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DEPARTMENT OF PUBLIC WORKS, CANADA

GEORGIAN BAY SHIP CANAL

REPORT

UPON

SURVEY, WITH PLANS AND ESTIMATES OF COST

1908

OTTAWA
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EXCELLENT MAJESTY
1909

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DEPARTMENT OF PUBLIC WORKS, CANADA

GEORGIAN BAY SHIP CANAL SURVEY

OTTAWA, January 20, 1909.

Honourable WILLIAM PUGSLEY,
Minister of Public Works,
Ottawa, Canada.

SIR,—The government surveys and investigations regarding the feasibility and probable cost of a deep waterway from the Great Lakes to the Seaboard, by way of the French and Ottawa rivers, initiated in 1904, by the Honourable C. S. Hyman, Minister of Public Works, under authority of parliament, and continued under your direction, have led your engineering board to formulate the following results and conclusions :—

1st. That a 22-foot waterway for the largest lake boats (600 ft. x 60 ft. x 20 ft. draft) can be established for one hundred million dollars ($100,000,000) in ten years, and that the annual maintenance will be approximately $900,000, including the operation of storage reservoirs for the better distribution of the flood waters of the Ottawa river.

2nd. That the distance from Montreal harbour to French River village on the Georgian Bay is 440 miles. That the rise from Montreal harbour to the Summit of 659 feet can be overcome by 23 locks, ranging from 5 feet to 50 feet in lift, and that the descent of 98 feet from the Summit to Georgian Bay can be made by 4 locks, ranging from 21 feet to 29 feet in height of lift,—27 locks in all, connecting 23 navigable pool levels of various lengths.

3rd. That sufficient water may be stored within its own and adjacent watersheds to operate a summit level above Lake Nipissing. That to use the Lake Nipissing level as a summit would increase the cost at least $10,000,000 and introduce 12 additional miles of canal cutting. That the natural low water flow throughout the Ottawa and French rivers is more than ample to meet all the requirements. That the spring flood in the Ottawa river can be restrained by storage throughout its watershed so that, under extreme conditions, the reaches will not overflow; currents therein will not be over 3 miles per hour, and locks will be workable, that is to say, practically slack water navigation will obtain.

4th. That ordinary lift locks are best suited to the conditions found. That their minimum length should be 650 feet between inside gates, with 65 feet clear width, and 22 feet clear depth throughout.

That the gates should be of steel, and for safety there should be 2 pairs of upper gates, and 2 pairs of lower gates with additional lower unwatering gates, if necessary.

That the locks should be constructed of concrete with long approach piers of continuous cribwork at each end. That all locks will be on secure rock foundation.

5th. That there will be 18 main dams required, some of considerable size, all being on secure rock foundation.

That regulation by stop-log sluices is amply efficient in most of the cases encountered, and 'Stoney' sluices and overflow regulation are adapted to the remaining reaches.

6th. That excavated channels with sides showing above water should have a minimum width of 200 feet at bottom, and submerged channels a minimum width of 300 feet at bottom, with marking piers at intervals, and that the minimum depth throughout should be 22 feet. That the project presented contemplates:—

28 miles of canal excavation.
66 miles of channel dredging.
346 miles of river and lake with a width of 300 feet to a half mile.

That there are 116 curves of which 77 are of about one mile radius, and the remaining 39 of about half that radius.

7th. That the probable time taken by a lake freight boat of 12-mile maximum speed, without delays at locks or in meeting other boats, from French River harbour to Montreal would be 70 hours. That the season of navigation will average 210 days from May to November.

8th. That the proposed reaches will be generally held at about the ordinary high water level of their vicinity, and much of the area to be flooded is now inundated each spring, so no extensive damage to the farming districts will occur.

9th. That with a storage system as planned, and the tributary basins thereto required for the navigation project, a reliable water-power supply is secured at various dams amounting to 1,000,000 horse-power, which can be developed for about $50 per h.p.

10th. That an alternative route behind Montreal is entirely feasible and would cost $5,000,000 less than the front or St. Lawrence River route; the time of transit by the back route being less than one hour longer than by the front of Montreal, and having one lockage less.

11th. That locks 800 feet long and 75 feet wide would increase the total cost by $5,000,000. That building all locks to a depth of 24 feet so reaches might afterwards be deepened, would cost another $6,000,000. That a depth of 25 feet along the route behind Montreal for 16 miles to Sault au Recollet would cost $7,250,000, nearly $2,000,000 more than the 22-foot depth for the same distance. That increased depth up to 26 feet can be secured temporarily by filling the reaches above ordinary working level, and in a case of emergency will pass boats of 24

to 25-foot draft, if the terminal locks and those into Lake Nipissing are given a 26-foot depth, and slight additions made to the overflow dams.

12th. That no international waters are affected.

Your Engineering Board respectfully advise:

1st. That it is of great importance to continue every year the flow measurements of the Ottawa, Mattawa and French rivers, at low, ordinary and high water stages, in order to have continuous records of same, which will prove invaluable in the further development of the canal problem, in case of construction, and a better knowledge of the water-power possibilities.

2nd. That though it has been ascertained that the Ottawa river flood waters can be restrained partially, the preliminary investigations made disclose the fact that data is lacking upon which to base a definite and judicious storage scheme. Twenty thousand square miles of the upper drainage area is but little known, and a reconnaissance of each lake is necessary before the true storage value of the area can be stated.

Each of the larger tributaries—the Rouge, the Lièvre, the Gatineau, the Coulonge, the Black, the DuMoine, the Montreal, the Petawawa, and the Madawaska—requires to have its storage lakes definitely decided upon and the inflow, outflow and surface height recorded continuously for a period of several years.

Continuous records of this kind are the only data upon which the restraint of floods and the reserve of water for navigation and power purposes can be determined with accuracy. Their value depends entirely upon the length of time over which the records extend; it is, therefore recommended that the collection of this information be continued without interruption.

3rd. That this study be extended gradually to all the large river drainage valleys which are possible of development for navigation and power purposes.

4th. That an understanding be reached between the Federal and the provincial governments interested, governing the disposal and control of all water-powers, water lots and islands, on the proposed route, in view of the possible canalization of the rivers utilized, as is fully explained in this report under the heading of 'Water-powers.'

Attention is also called to the recommendations in regard to the conservation of forests in relation to water supply in the articles on 'Storage' and 'Water-powers.'

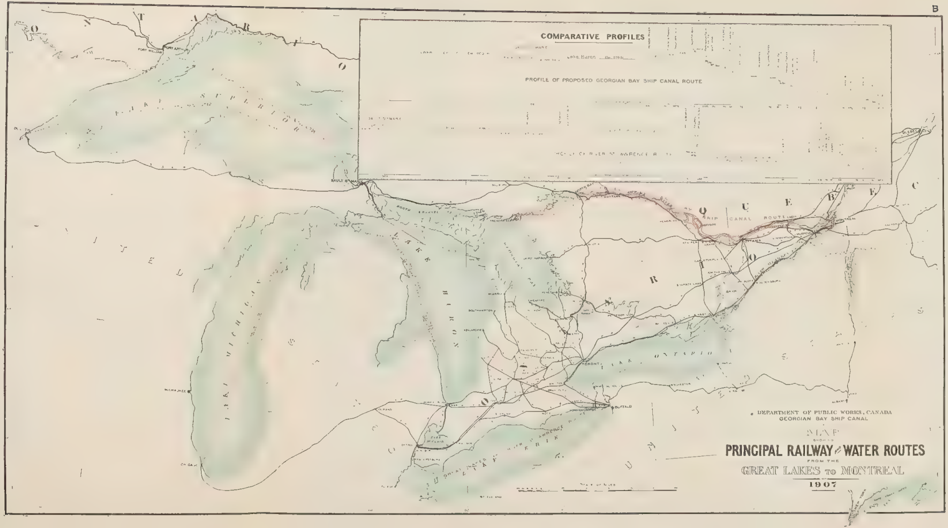
5th. That for a work of such magnitude as that proposed—one of the largest in the world—it would be in the interest of the government, if construction is to be proceeded with, to commission at least two of its engineers to visit some of the larger river canalizations and ship canals existing or at present under construction, and collect data as to results achieved and desirable improvements gained from actual experience; in fact, to study the world's experience in the development of waterways, modern methods of construction, and all matters connected

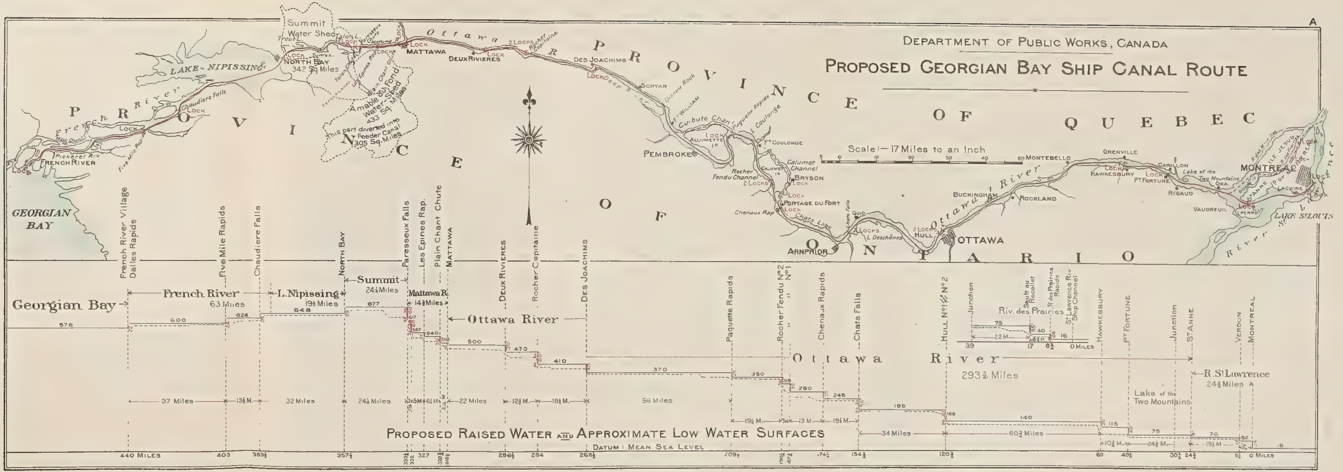
with their proper operation and administration. That such a step would lead to greater efficiency and economy, cannot be doubted.

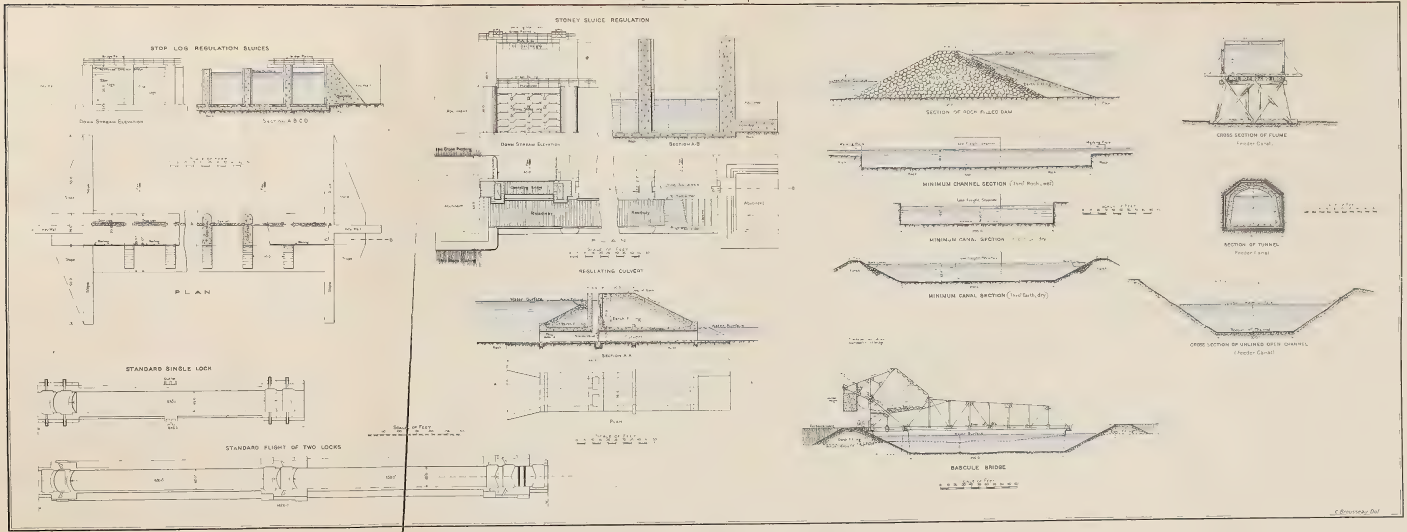
Respectfully submitted.

Board of Engineers .... ..

EUGENE D. LAFLEUR, *Chief Engineer.*
A. ST. LAURENT, *Engineer in Charge.*
C. R. COUTLEE, *District Engineer.*
S. J. CHAPLEAU, *District Engineer.*


B
COMPARATIVE PROFILES
Lake Huron
PROFILE OF PROPOSED GEORGIAN BAY SHIP CANAL ROUTE
ONTARIO
LAKE SUPERIOR
FORT WILLIAM
PORT ARTHUR
SAULT STE MARIE
NORTH BAY
OTTAWA RIVER
QUEBEC
SHIP CANAL ROUTE
OTTAWA
MONTREAL
LAKE HURON
LAKE MICHIGAN
LAKE ONTARIO
LAKE ERIE
TORONTO
BUFFALO
SOUTHAMPTON
MILWAUKEE
CHICAGO
ALBANY
NEW YORK
DEPARTMENT OF PUBLIC WORKS, CANADA
GEORGIAN BAY SHIP CANAL
MAP
SHOWING
PRINCIPAL RAILWAY AND WATER ROUTES
FROM THE
GREAT LAKES TO MONTREAL
1907


A
DEPARTMENT OF PUBLIC WORKS, CANADA
PROPOSED GEORGIAN BAY SHIP CANAL ROUTE
Scale:— 17 Miles to an Inch
PROVINCE OF QUEBEC
PROVINCE OF ONTARIO
GEORGIAN BAY
LAKE NIPISSING
NORTH BAY
342 Sq. Miles
Summit Water Shed
MATTAWA
DEUX RIVIERES
DES JOACHIMS
PEMBROKE
BRYSON
ARNPRIOR
OTTAWA
HULL
BUCKINGHAM
ROCKLAND
MONTEBELLO
GRENVILLE
HAWKESBURY
CARILLON
RIGAUD
VAUDREUIL
MONTREAL
LAKE ST. LOUIS
Ottawa River
French River
Amable du Fond Water Shed 433 Sq. Miles
This part diverted into Feeder Canal 305 Sq. Miles
Georgian Bay
French River 63 Miles
L. Nipissing 19½ Miles
Summit 24½ Miles
Mattawa R. 14½ Miles
Ottawa River
Ottawa River 293¾ Miles
R. St. Lawrence 24¾ Miles
Lake of the Two Mountains
Riv. des Prairies
PROPOSED RAISED WATER AND APPROXIMATE LOW WATER SURFACES
DATUM: MEAN SEA LEVEL
440 MILES
0 MILES


STOP LOG REGULATION SLUICES
Down Stream Elevation
Section A B C D
PLAN
STANDARD SINGLE LOCK
STANDARD FLIGHT OF TWO LOCKS
Scale of Feet
STONEY SLUICE REGULATION
Down Stream Elevation
Section A-B
Abutment
Operating Bridge
Roadway
PLAN
Scale of Feet
REGULATING CULVERT
Water Surface
Section A A
Plan
Scale of Feet
SECTION OF ROCK FILLED DAM
MINIMUM CHANNEL SECTION (Thro' Rock, wet)
MINIMUM CANAL SECTION
MINIMUM CANAL SECTION (Thro' Earth, dry)
BASCULE BRIDGE
Scale of Feet
CROSS SECTION OF FLUME
Feeder Canal.
SECTION OF TUNNEL
Feeder Canal
CROSS SECTION OF UNLINED OPEN CHANNEL
(Feeder Canal)
C Brousseau Del


SL
45

SURVEY

STAFF ORGANIZATION.

In 1904, the sum of $250,000 was granted by parliament for the purpose of commencing a detailed survey of the proposed waterway from Georgian Bay to Montreal, a distance of 440 miles.

This amount was made available at the close of the session, August 10, of the same year, and in accordance with the directions of the Honourable C. S. Hyman, Minister of Public Works, I assumed immediate charge and commenced at once the work of staff organization and the purchase of the necessary equipment.

After many consultations with the chief engineer my final instructions were, in order to fully meet the object in view, that the survey be of such a character that when the notes were reduced and plotted there could then be projected upon the plans, the best location possible for a canal at least 22 feet in depth, with a bottom width of 300 feet, from which profiles could be drawn and a correct estimate made of the amount and character of material in excavation and embankment, nature of various foundations and final design of locks, dams, regulating works and other structures; also the right-of-way and definition of flooded area.

It was, moreover, understood that the whole of the information to be shown on the plans, as topography, contours, soundings, physical features of the route, &c., should be obtained from actual surveying and that plans from previous partial surveys should be used only as preliminary information and for general guidance, with the exception of the French River section which had been surveyed in 1901 by the late J. W. Fraser for a 22-foot waterway. It will, however, be seen further in this report that supplementary surveys of the French river had to be undertaken on account of desirable changes in the project.

At such points where several possible routes for the canal existed and when the best location could not be determined by exploration alone, my instructions were to survey and develop the different routes in order to arrive at a selection by comparison of their relative merits as to length, curvature, probable cost, &c.

To this end and to get the results within a reasonable time it was deemed necessary to place a large force of engineers in the field.

From the close of the session until September 27, the date on which the different parties were formed at Ottawa, it was my duty apart from departmental work, to complete all arrangements so as to be in a position to commence work as soon as the staff could be organized.

Camp equipment consisting of tents, blankets, cooking utensils, &c., necessary for nine parties of fifteen men each were purchased. Surveying instruments were ordered to be delivered within the shortest possible time and boats of a suitable character for the swift and dangerous waters to be surveyed were ordered to be built according to special design. A set of survey rules as given in Appendix A was prepared in order that the work done by the different parties be as efficient and uniform as possible.

The formation of a Board of Engineers to direct and control the survey was discussed, but was finally abandoned as it was decided that the work should be carried out under direct departmental control with a member of the permanent staff as engineer in charge and executive officer, and such temporary additional engineering

help as would be required. In this way, no accounting office was organized and all work in regard to the payment of accounts was performed by the accountant's branch of the department.

In order, however, to derive all the benefits conferred by a Board of Advisory Engineers on all works of great importance and of unusual character, it was understood that the chief engineer, the engineer in charge of the survey and the district engineers, would form a nominal board to discuss all matters pertaining to the work, decide as to the general lines of the canal, size and character of locks, depth and width of channels, curvature, unit prices to be applied to quantities, &c., &c., a conclusion to be reached only after the fullest discussion. This was with a view of giving more weight to the project as elaborated, more value to the final report and the estimate of cost.

STAFF AT HEAD-QUARTERS.

The special staff at head-quarters was constituted as follows:—

The engineer in charge.
Three district engineers, inside and outside service.
One assistant engineer.
One secretary.
Force of draftsmen, under charge of a chief draftsman.
One store-keeper.
Force of typewriters and clerks as required.

As no space was available in the departmental buildings, offices were secured elsewhere.

DIVISION OF TERRITORY.

The territory to be surveyed was divided into three districts, designated as 'Montreal,' 'Ottawa' and 'Nipissing,' each in charge of a district engineer with head-quarters in Ottawa.

Each district was sub-divided into three or more sections, each in charge of a sectional engineer, who generally had under his control, two assistant engineers, two rodmen, two chainmen, one foreman and seven or more labourers, according to the requirements of the work.

The original number of surveying parties placed in the field was nine, but this was increased subsequently, by the addition of a precise levelling party, three test-boring parties, one hydraulic investigating party and one party for Lake Nipissing and canal feeder surveys.

LIMITS OF DISTRICTS AND SECTIONS, AND SUMMARY OF WORK ACCOMPLISHED.

MONTREAL DISTRICT.

This district embraced sections 9, 8 and 7 of the Ottawa river and covered the territory between the mouth of the Gatineau river and the eastern end of Montreal island, a distance of 140 miles.

As the river divides into two distinct main branches at the foot of the Lake of Two Mountains, the length of river and lake waters to be surveyed was about 170 miles. The district was placed under the able direction of Mr. C. R. Coutlee, Mem. Can. and Am. Soc. C.E.

Section No. I.—*Engineer, L. .R Voligny, C.E., in charge.*

This section embraced surveys practically all around the Island of Montreal: 1st. From Ste. Anne de Bellevue to Montreal through Lake St. Louis and the Lachine rapids. 2nd. From Ste. Anne de Bellevue, following the north shore of Montreal island, through Rivière des Prairies, as far as Bout de l'Isle, at the junction with the St. Lawrence river, about 10 miles below the eastern limits of Montreal harbour.

The entire north side of Lake St. Louis, the whole of Ile Perrot, and all the islands from Ste. Anne de Bellevue to Lachine were traversed, levelled and contoured. A belt of soundings 2,000 feet wide was carried down from Ste. Anne de Bellevue to Dorval. The north shore of the St. Lawrence river was developed from the town of Lachine to Victoria bridge, including Nun's island and Ile au Heron at Verdun. Soundings from Verdun to Victoria bridge were made over the whole of the north half of the river. The Lachine canal was traversed and cross-sectioned every 400 feet from Lachine village to St. Paul and thence down to the St. Lawrence river at Verdun.

The shore of Lake of Two Mountains was traversed and contoured from Ste. Anne de Bellevue to Ile Bizard and the Rivière des Prairies was carefully surveyed, cross-sectioned, and levels and soundings taken all the way down to Bout de l'Isle.

A system of triangulation was also made, tieing in all the work on Lake St. Louis.

Bench marks were established at least every mile and gauges were placed and read continuously at many points.

A trial line was run across Montreal island from a point on the Rivière des Prairies to the St. Lawrence river opposite the head of Ste. Therese island, and cross-sections taken for a width of 2,000 feet.

A traverse was also run around the point of the island at Bout de l'Isle to tie in the survey system with that of the Hydrographic survey of the St. Lawrence river, from which the St. Lawrence shore of Montreal island was accurately obtained up to Victoria bridge, where another connection with the Hydrographic survey had been made through the Lake St. Louis line.

The field work of this section was completed at the end of October, 1905, and the junior assistants and labourers paid off. Mr. Voligny was retained for office work, and the first assistant engineer, Mr. E. A. Forward, was directed to join section No. 2, in the Nipissing district, to help in completing the work, after which he was engaged at the office in Ottawa.

Section No. 8.

This section, which was placed under Mr. C. E. Macnaughten, extended from the Carillon rapids down through the Lake of Two Mountains and the Ste. Anne rapids as far as the head of Lake St. Louis, and also to the head of Rivière des Prairies, a direct distance of about 25 miles, but which required with trial routes over 50 miles of surveying.

Lake of Two Mountains being a relatively large body of water, though it was not necessary to cover it entirely with soundings, very large areas on different courses had to be investigated, requiring a large amount of triangulation. Many low-lying islands and areas of low lands around the lake had to be traversed and contoured for a possible regulation and maintenance of the lake to a higher elevation than the ordinary level. An alternative route north of Ile Bizard was also surveyed.

From Carillon to Rigaud bay the river is half a mile wide, and the soundings were made from shore to shore. From north of Jones island to Ste. Anne de Bellevue a width of 1,500 feet was sounded, and an alternative line of the same width was examined south of Jones island.

Bench marks were established on both shores and the levels thoroughly checked. The highest water contour line on record on Lake of Two Mountains was traced on both shores and simultaneous gauge readings taken at many points at different stages of the lake.

At the end of August, 1905, Mr. Macnaughten had completed his field work, and he was directed with his assistants to proceed to Pembroke to make the survey of the Upper and Lower Allumette channels, as mentioned further in this report.

Section No. 7—Engineer, E. E. Perrault, in charge.

From the mouth of the Gatineau river, opposite Ottawa, to Carillon rapids, a distance of 66 miles.

The soundings between Ottawa and the head of the Carillon rapids at Hawkesbury did not present any difficulty, on account of the favourable configuration of both shores and the low currents in the river. Along this stretch, however, there are large tracts of low lands generally submerged at high water, which required considerable work in traversing and in the determination of contours for any rational raised water surface which might be projected. Owing to the width of the river at L'Orignal lake, the soundings there occupied considerable time.

Through the Grenville rapids a sufficient number of soundings were taken, and both shores from Hawkesbury to the Carillon dam were carefully cross-sectioned. Bench marks were established and gauges maintained for continuous record of water levels.

Field work on this section was completed at the end of September, 1905. The rodmen, chainmen and labourers were discharged, and the two principal engineers transferred to Ottawa for work on the general plans. The second assistant engineer, Mr. E. S. Miles, was transferred to section No. 4 for work on the Culbute channel.

OTTAWA DISTRICT.

This district embraced sections 6, 5 and 4 of the Ottawa river and covered the territory between the head of Des Joachims rapids and the mouth of the Gatineau river, below the Chaudière falls at Ottawa, a distance of about 140 miles.

The length of the river valleys to be surveyed, however, was nearly 200 miles, on account of the river dividing into two main branches at different points.

The district was divided into three main sections and placed under the direction of Mr. E. J. Rainboth.

In February, 1906, Mr. Rainboth resigned to resume private practice, and as most of the surveys were completed, this part of the Ottawa river was added to the Montreal district, under the direction of Mr. C. R. Coutlee.

Section No. 6.

This section extended from the head of the Chats rapids to Ottawa, a distance of about 35 miles and was originally placed under Mr. Alexander McDougall, Mem. Can. Soc. C.E., who remained in charge from September 27 to December 31, 1904, when he was appointed as hydraulic engineer for the collection of hydraulic data regarding the proposed canal. Mr. W. G. Warner, who had been acting as first assistant engineer was promoted to the vacancy. He died, however, in April, 1905, after a few months of faithful and valuable services and was succeeded by his first assistant engineer, Mr. H. A. K. Drury. Mr. Drury remained in charge until after the completion of the field work, resigning in June, 1906, to accept a position with the Board of Railway Commissioners.

The survey work on this section was particularly heavy at the Chats rapids and falls, where the river drops 50 feet and is divided into numerous channels. Over 300 islands were triangulated, traversed, and contoured, as well as both the Ontario and Quebec shores. Several lines were run at the Chats and back of Hull and many sites for dams investigated. A complete survey of Brewery creek was made. All river stretches were covered by close soundings, and through Chats lake and Deschenes lake soundings were taken on a strip wide enough to cover all possible desirable channels. A complete net of levels was run and bench marks established along both shores for the entire section. Cross-sections were run over all low areas for contours, and lines of railways on both shores were included in the survey whenever there was a possibility of them being affected by any condition of raised water surface.

A complete survey of the Chaudière falls, with all power canals, tail races, slides, &c., was made and soundings taken where possible.

This party finished the field work in January, 1906, and the engineers commenced their office work at Ottawa.

Section No. 5.

Engineer, A. Robert, who, I regret to say, died shortly after the completion of the field work.

This section extended from Fort Coulonge, through Calumet, Portage du Fort, Chenaux rapids to the head of Chats rapids, a distance of about fifty-six miles.

Below Fort Coulonge numerous islands and channels had to be surveyed.

A low valley called Grand Marais, extending from Coulonge village to a sharp bend in the river some seven miles below, was developed as a possible short cut.

A few miles below Coulonge, the river divides into two branches forming a large island known as Calumet. The north channel is called Calumet and that on the south is known as Rocher Fendu. Only the Calumet channel was developed by party No. 5, the survey of the Rocher Fendu being left aside until an opportunity offered to make a complete reconnaissance through it, in order to decide whether it was advisable to survey it in detail. This was done during the winter of 1906 and a supplementary party placed at work under Mr. C. E. Macnaughten, who took all necessary soundings, contours and cross-sections.

In carrying out the triangulation, traverse, topography, soundings, levels, &c., to the east end of the section on Chats lake, party No. 5 investigated a gulley passing back of Portage du Fort, and all possible locations which might offer some advantages over the main river route. Bench marks were established as close as possible, and the soundings on Chats lake were completed in January, 1906, when the party was discharged and the engineers transferred to head-quarters for work on the plans.

Section No. 4a.—Engineer C. E. Macnaughten, in charge.

From lower end of Allumette lake, about 6 miles above Pembroke to foot of Allumette island, a distance of about 24 miles.

As Mr. Macnaughten had just completed section No. 8 of Montreal district, instructions were issued to him at the beginning of September, 1905, to survey the above-mentioned part of the Ottawa river.

Work commenced on September 12, making a survey of the shore line, surveying the islands in the Lower Narrows, also Morrison's and Moffat's islands, and on down through the lower lake and Paquette rapids to the foot of Allumette island.

The islands in Paquette rapids were located and traversed, and in December, Bellows bay, Cranberry lake and the east end of Allumette island were surveyed.

Levels were carried along and bench marks established. Both shores and islands were contoured for all possible combinations of improvements and raised water surface.

Soundings of that wide stretch of the river were commenced, at the beginning of December as soon as the ice was considered safe enough to carry men and teams. Unfortunately, on account of the mild weather and swift currents, large areas did not freeze sufficiently and soundings had to be taken there from boats, which in cold weather is slow and difficult work. Altogether over 14,300 soundings were taken, and the work completed about the middle of January, 1906.

Section No. 4.

Engineer G. L. Griffith, who resigned in February, 1905. Replaced by Mr. A. J. Matheson, Mem. Can. Soc. C.E. From the head of Des Joachims rapids to Fort Coulonge is a distance of about 86 miles.

The survey work of this section was very heavy. The river is very wide for long stretches and dotted with islands. It involved a large amount of triangulation apart from the regular traverses on both sides of the river forming the base lines for developing contours and for taking soundings.

At Des Joachims rapids, which were surveyed in great detail, it was decided to investigate a short cut from the head to the foot of the rapids through what is known as the McConnell Lake valley, which is supposed to have been, at one time, an old branch of the river, having a length of about 4½ miles. Of this distance, McConnell lake occupies about 2 miles in length of deep water, with an average width of nearly 1,000 feet, the valleys above and below connecting with the river being relatively low ground. This was developed sufficiently to enable a comparison to be made with the main river route.

From the foot of the rapids down for a distance of about 28 miles, there is a magnificient stretch of river, called the 'Deep river,' with a good wide channel over 40 feet in depth. This did not require very close sounding, nor very many contours on account of high banks.

But below that stretch the river becomes more shallow and widens into a lake called the Upper Allumette, containing numerous shoals and over 200 islands, with a tortuous channel reaching to the lower Narrows. All the islands were surveyed and contoured, the shoals and all channels carefully sounded and investigated as to the best possible route for the waterway.

Below Allumette lake is Allumette island, where the river divides into two channels, the South or Pembroke channel, and the North or Culbute channel.

About the end of August, 1905, it was found that party No. 4 could not undertake the survey of these two channels and complete them early in 1906, as desired. Therefore, Mr. Matheson was instructed to limit his survey to the Culbute channel, and Mr. Macnaughten was directed to survey the Pembroke branch, as previously stated.

The contours, cross-sections, soundings, levels, &c., of the Culbute channel and Coulonge lake were completed in January, 1906, the men were discharged and office work begun at Ottawa by the engineers.

NIPISSING DISTRICT.

This district covered that part of the Ottawa river that lies between Des Joachims rapids (which are about 40 miles above Pembroke) and the Town of Mattawa; then the Mattawa river, the Summit lakes (Talon, Turtle and Trout), Lake Nipissing and the French river to Georgian Bay on Lake Huron, a distance of 171 miles, which was increased to about 260 miles with the alternative routes surveyed.

The district was placed under the able direction of Mr. S. J. Chapleau, Mem. Can. and Am. Soc. C.E.

The country lying between Des Joachims rapids and Lake Nipissing was divided into three sections, numbered 3, 2, 1, a lake party being afterwards formed to investigate that part of Lake Nipissing which lies between North Bay and Rivière des Vases, on the northeast shore of the lake, across to Frank's bay or the upper entrance of the French river.

Section No. 3.—Engineer Wm. Cross, Mem. Can. Soc. C.E., in charge.

From Johnson's rapids to Des Joachims rapids on the Ottawa river, a distance of 56 miles.

This section includes the Deux Rivières and Rocher Capitaine rapids.

The entire river valley was triangulated, closely traversed and topography taken in detail.

Soundings were taken everywhere except in the rapids, where it was impossible to ascertain the depth of water otherwise than by approximation.

Water level gauges were established throughout the section and their records maintained. Preliminary reconnaissances of the different swift currents of the Klock, Deux Rivières and Rocher Capitaine rapids showed that one continuous location was possible, and the topography was confined to the valley of the river.

The country in this section was exceptionally rough and very thickly wooded, in consequence of which the necessary topography for the project and estimate was difficult to obtain.

All contours, soundings, levels, &c., were, however, completed at the end of December, 1905, and the engineers recalled for office work or for further field work elsewhere, and the balance of the party paid off.

Section No. B.—*Engineer, H. P. Bell, Mem. Can. & Am. Soc. C.E., in charge.*

This section extended from Lake Talon, following the course of the Mattawa river to its junction with the Ottawa river, thence to the foot of Johnson's rapids, a distance of about 24 miles.

Three possible routes between the Talon lake level and Lake Plain Chant on the Mattawa river were investigated. One from Sand Bay on Talon lake to the Paresseux falls on the Mattawa, one following the natural valley of the Mattawa from Talon chute, and the third, passing from Talon chute also, to the lower end of Pimisi lake, thence across to Johnson's lake, Smith's lake, Crook's lake, Moore lake, and running into the Mattawa again through a blind arm at the western end of an expansion of the river Mattawa, called Lake Plain Chant.

The investigation and close survey of other routes than the Mattawa itself, at its upper end, were necessitated on account of its narrow width and irregular course, two changes of direction being nearly of 90° each within a short distance, and occurring in close proximity to possible lock structures.

The Pimisi and Johnson lakes location necessitated a survey for the diversion of the Canadian Pacific railway main line in order to prevent two crossings.

In all over 50 miles of possible routes were surveyed on this section, and all necessary information collected for development and selection of best location. Gauges

were established for continuous records of water levels, and discharge measurements of the Mattawa and tributaries were made. Part of the country surveyed was exceptionally rough and thickly wooded.

This section was completed in December, 1905, the party disbanded and the engineers transferred to Ottawa for completion of plans, computations, &c.

Section No. v.—Engineer, A. J. McDougal, Mem. Can. Soc., in charge.

From Lake Nipissing over the height of land separating the waters of the Ottawa and Lake Huron watersheds, through Trout, Turtle and Talon lakes, to head of the Mattawa river, is a distance of about thirty miles, but involving the examination of several alternative routes. Five traverses were made from Lake Nipissing to Trout lake with sufficient topography to determine the best route through the divide, two by the Chippewa creek; two through the Ojibwaysippi route and one at the Rivière des Vases.

From Turtle lake to Talon lake three routes were investigated; one by way of the Little Mattawan river, one from the western end of the latter to an arm of the south shore of Lake Talon, known as Spottswood's bay. Another route was investigated by track traverse, from Turtle lake into the Kai-bus-kong, through Price, Cross and Frog lakes and the two pools above the lower rapids of the Kai-bus-kong.

A suggested route from Lake Nipissing to Lake Nasbonsing and down the Kai-bus-kong was found to be impracticable, and was not surveyed on account of Lake Nasbonsing having an elevation of 137 feet above Lake Nipissing, whereas Trout lake has a summit elevation of but 22 feet above Nipissing.

All economical routes were closely surveyed to any condition of raised or lowered water surface. A number of gauges were established at different points, their record continually kept and their zeros referred to permanent bench marks.

The field work on this section was completed in August, 1905, and the party was transferred to the French river for supplementary work which is described in the part relating to the French river.

Lake Nipissing Party.—Engineer, F. H. Peters, Mem. Can. Soc. C.E., in charge.

During December, 1904, a party was formed to take all the soundings required between the northeast shore of Lake Nipissing, in the vicinity of North Bay, and Frank's bay, at the entrance of the French river. This was in order to connect with the surveys and soundings made in 1901 by the late J. W. Fraser. Two routes were investigated, one to the north and one to the south of the Manitou islands. These soundings were begun early in January, 1905, and were completed in about three month's time. For these routes a strip nearly one mile wide was covered by soundings.

On the completion of this work the party was detailed to establish the 5 and 10-foot contours above the high water plane of Lake Nipissing from a point west of the town of North Bay to Rivière des Vases.

Gauges were established at North Bay and across the lake at Frank's bay to which the soundings of the lake party are referred. In all about thirty-six miles in area of soundings were taken.

This party was temporarily detached from Lake Nipissing work to carry on a preliminary investigation of a possible line through Kai-bus-kong lake at the Summit level. This line was investigated sufficiently to show its value as compared with the more economical routes as adjudged by comparative centre line profiles and careful inspection and it was deemed inefficient to put it under close detail.

Upon the completion of this the lake party was detailed to connect by a close triangulation system, the permanent points of section No. 1 on the shore of Lake

Nipissing, and also the ends of a seven mile base line laid down previously, with the initial points of the French river triangulation at Frank's bay.

Triangulation across Lake Nipissing, including islands and points on the main shores covering territory in the immediate vicinity of the proposed route was made. It was the intention to throw a triangulation net all over the lake, from whose points an investigation of the 5 and 10-foot contours above high water might be made through reconnaissance with hand level and sextant, but by reason of the large expenditure involved and lack of a proper boat to do this work in safety, it was abandoned.

The information required, however, was collected, by visiting the different low places, which were likely to be affected by raising the lake surface; some of the places visited were North Bay, Sturgeon Falls, East Bay, Beaucage, Cache Bay, Callender and West Arm.

Upon the completion of the triangulation across Lake Nipissing, the lake party was employed to connect the Lake Nipissing permanent bench marks with the permanent bench marks at French River village on Georgian Bay. This line of levels was carried through by direct check levelling and by water level transfer along admissible stretches, following the French River course, and terminating at a permanent bench mark at French River harbour, to which the zero of the automatic gauge at that point is tied. This work was completed in October, 1906, and the party discharged, excepting the engineers who were retained for work required in other localities.

Amable du Fond Feeder Survey.

During the fall of 1905, after an exhaustive study of the data collected so far in regard to the available water supply at the Summit level, it was decided to carry out surveys to determine the cost of diverting the Amable du Fond river—a tributary of the lower Mattawa—by flume or open cut, in order to obtain its discharge into Talon lake above the chute, instead of into the Mattawa river at the LaRose rapids.

This was advisable in view of the result of the hydraulic investigations in regard to the summit outflow, which was deemed as probably insufficient to meet the requirements of a large traffic.

It was ascertained that the Amable du Fond drained an area larger than the watershed of the Summit lakes; therefore, it was of great importance to find out if it could not be diverted to the Summit basin.

A special party was organized for this investigation, in charge of Mr. F. H. Peters, under Mr. S. J. Chapleau. Work began during the last week of November, 1905, and was completed in March, 1906.

The instructions to this party were to connect the Kioshkoqui lake level (the source of the Amable du Fond) with the summit swamps of Sparks creek which discharge into Lake Talon; follow the shortest traverse for the grade found and develop the adjacent topography in close contour. A total length of over 30 miles of line was developed in this connection. The possibility of raising and storing water in the lakes forming the head of the Amable du Fond was also investigated. Upon the completion of this field work, the engineer in charge was transferred to Ottawa.

French and Pickerel River Surveys.

After a close study in the office of all the information available relating to the French river, it was found desirable to supplement the surveys made in 1901 by the late J. W. Fraser for the Department of Public Works, in order to be in a position to develop a uniform scheme of improvements for the entire route.

As the survey on the Summit section (No. 1) had been completed during the last week of August, 1905, instructions were issued to Mr. A. J. McDougal, the engineer in charge, to carry an accurate triangulation from Frank's bay on Lake Nipissing down to French River Harbour on Georgian Bay. Mr. Fraser's survey had been per-

formed entirely in the winter time, and the topography and soundings were based upon a single traverse carried on the ice, and very few stations were permanently located on the shore. The triangulation ordered enabled our system to be tied to the base or traverse of Mr. Fraser's survey, permitted a check on the same, and allowed additional soundings and topography to be taken, where considered necessary, in order to supplement the large amount of information shown on his plans, without making a complete re-survey of the route.

During the fall of 1905, the triangulation, supplementary soundings and topography were carried down along the main channel of the river to a point near the second rapid below the Recollet falls, in all about 47 miles.

Permanent transit stations of the previous departmental survey were tied in from our triangulation points,thus closely connecting the two surveys.

For obtaining supplementary topography many additional cross-sections were taken at different points, as well as complete surveys made of many islands and branches of the river.

Near the western end, the work was very much delayed on account of a large number of logs completely obstructing the river, and which it was impossible to have removed sufficiently to permit the use of boats.

The survey, therefore, was not completed through to the Georgian Bay level, as was expected, but had to be abandoned during the second week of November, befor the formation of ice, to be resumed the following spring.

The engineering staff forming this party was engaged during the winter in office work, and in May, 1906, again proceeded to the French river to complete the work left unfinished and also to project an entirely new survey of that part of the French river waters, known as the Pickerel river, lying between Ox lake on the French and the Horseshoe falls, and from the latter point to the main French at mileage 37 below Frank's bay.

As the lower part of the main French was found to be very narrow in many places and confined between high rocky bluffs, a large amount of exploratory work was done during the previous season, looking for a betterment of the route, if possible.

The Pickerel river, running parallel to the main French from the Horseshoe falls down to its junction with that river at Ox lake, seemed to offer some advantages which were deemed of sufficient importance to investigate closely. Therefore, it was decided to develop the Pickerel river by close soundings, contours, topography, &c., for a possible route for canal purposes. This work was completed about the middle of July, 1906, the men paid off and the engineers directed to return to Ottawa for office work.

Hydraulic Engineering Party —Engineer, Alexander McDougall, Mem. Can. & Am. Soc. C.E., in charge.

The duties assigned to this party were the systematic gauging of all utilized streams, the collection of all hydraulic data concerning them, the investigations regarding the Summit water supply, the study of a system of storage reservoirs for the Ottawa river, and also securing as much information as possible about water-powers.

Mattawa River Gaugings.

Late in February, 1905, a thorough reconnaissance of the Mattawa river was made between Talon lake and the Little Paresseux rapids for the purpose of establishing a permanent gauging station, which could be used in regard to the summit flow at all seasons of the year. After making several trials with the current meter at various sections below Pimisi bay, the Narrows, 2,800 feet above Talon chute, was found to be the only channel in that vicinity that could give satisfactory results.

A total of fifty measurements were made below Talon chute and at Talon Lake Narrows.

On account of the bed being rough at the adopted gauging station there are some discrepancies in depth, but these were unavoidable.

A cable and car was erected for this section and used continuously during the summer of 1905.

Gauges were placed, one at the head of Talon chute and also one below Pimisi bay.

Between March 3 and June 14, 1905, thirty-two current meter measurements were made of Kai-bus-kong river, a tributary of the Mattawa; twenty-nine of these were taken from the highway bridge, about two and one-half miles down stream from Bonfield.

One measurement was made during the winter when the ice averaged over 2½ feet in thickness at the bridge; the remaining two were made some distance further down the stream.

Gauges were placed, one on a pier just above the dam at Bonfield, and one at the lower side of the highway bridge at the gauging station. The latter was used in constructing the discharge curve.

Below Turtle Lake.

Twelve current meter measurements were made of the flow from this lake, at the foot of Whitefish bay, between March 8 and May 24, 1905. During high water some difficulty was caused by the lumbermen driving the stream while measurements were in progress. Two of these had to be discarded in plotting the discharge curve owing to logs jamming below the gauging section, thus raising the water at the gauge without increasing the flow.

Gauges were placed one on a pier above Turtle lake dam, and one at the head of Whitefish bay.

Some distance above Mattawa, six current meter measurements were made of the river, four in 1905, one in the spring of 1907, and one in May, 1908.

Gauges were read from May 15, 1906, to the end of March, 1907, at the head and foot of the electric power plant.

A considerable number of measurements were made of the Amable du Fond river, a tributary of the Mattawa, discharging below Talon chute. The special attention paid to this river was on account of the possibility of diverting its waters to the Summit level.

A total of one hundred and twenty-eight current meter measurements were made, one hundred and twenty-two in the vicinity of Booth's Farm, four at a place one and one-half miles below Eau Claire and two at the outlet to Kioshkoqui lake.

The gauge used in constructing the discharge curve was immediately below the section selected for the majority of the discharging measurements. During the early part of the summer of 1906, the river was for a long period filled with logs and these affected the velocity of the stream to such an extent that a separate dischagre curve had to be plotted. Forty-eight of the measurements were made while the channel below was filling up with logs.

Current meter measurements were made of the flow from the following lakes: Kioshkoqui, Mink, Manitou, Three-Mile, Tea and Indian, which were all investigated for storage and possible supplementary water supply for the Summit level.

Current meter measurements were also made in April, 1906, of Depot, Boom and Wisawasa creeks.

French River Gaugings.

Twenty measurements were made of the three outlets to Lake Nipissing at lake elevations ranging from 638·35 to 642·72, and an estimate made for the three channels at what was assumed to be extreme high water.

The gaugings made on September 6 and 7, 1907, could not be used in plotting the discharge curve, the channel above the Big Chaudière being completely filled with logs, thus obstructing the channel and decreasing the discharge without the lake level being materially reduced; dams under construction at the western outlets also affected the lake but to a much greater extent.

The gauge used in connection with these measurements being located at the head of the lake, and subject to variation in level caused by strong westerly winds it was necessary to ascertain the level at the foot of the lake. This was done at the time of the last three measurements during a calm day, and the level was found to be practically the same.

Two trips were made to the mouth of this river, and its various outlets measured, making a total of twelve gaugings with the current meter, and one set of float measurements of the Bass channel.

Ottawa River Gaugings.—Foot of the Lake of Two Mountains.

Twenty-six current meter measurements were made of the different channels, divided as follows:—

Seven below Vaudreuil, including one made in March, 1907, of the back water from the St. Lawrence.

Six at Ste. Anne's.

Four at Cartierville and two at St. Genevieve.

Seven of the Mille Isle river, three of which were made from the bridge at St. Eustache, two from the C.P.R. bridge at Rosemore, and two, about one and one-half miles above St. Eustache.

Above Carillon.

Four current meter measurements were made about two miles above Carillon, three with the Price meter, one with the Haskell, using the low velocity wheel with the latter. The North river was also gauged when the last two measurements were made and the other large streams between Carillon and Montreal investigated in order to estimate the total discharge at the foot of the Lake of Two Mountains. The sections at Carillon are not suitable during low water as the velocity averages only 0·5 feet per second during that period.

All these measurements were made from a gasoline launch and the distances secured with a transit and pocket sextant.

Besserer's Grove.—Ten miles below Ottawa.

Sixteen current meter measurements were made at this section at elevations ranging from 128 to 142·00, the latter elevation being over 1½ feet below the average high water for sixty years.

With one exception all these gaugings were made with the large Price meter. The work was done from a gasoline launch and a transit used on all occasions for distances.

Gaugings were made of the Gatineau river at the same time in order to give the flow above Ottawa.

Chaudière Falls.

Forty-seven current meter measurements were made of the different channels at the Chaudière, two float measurements, and several estimates by adding on increased sectional area, &c. These were made between June 20 and August 22, 1905, and between September 27 and November 19, 1906. Several of these gaugings had to be discarded owing to a variation in the load while the measurement was in progress.

Bench marks tied into the precise level system were read during each metering, both at the head and foot of the different powers.

Above the Chaudière, four current meter measurements were made, three just below Skead's old mill, and one at the head of the Little Chaudière rapids. The level of the water was ascertained at the different sections and at the foot of Deschenes lake at the time of the gaugings.

A transit and range poles were used for the first three measurements; the latter was made in March, 1906, through the ice.

Calumet Channel.

Three current meter measurements were made of this channel in the vicinity of Campbell's Bay, one in May, one in November of 1905, and one in the spring of 1907. The gauge at Bryson was used in connection with these measurements in plotting the discharge curve.

Transit and range poles used for distances and line.

Gower Point.

Four current meter measurements were made directly opposite this village, three in 1905 and one in the spring of 1907. The gauge used with these measurements in plotting the discharge curve was about 100 feet below this section.

Below Allumette Island.

Three current meter measurements were made at Spottswood Ferry, two in 1905, and one in the spring of 1906.

Culbute Channel.

Three current meter measurements were made: two near Waltham in 1905, and one from the bridge at Chapeau village in the spring of 1907.

Ferry used for the two former measurements.

Deux Rivières.

Eleven current meter measurements were made about four miles above Deux Rivières at Klock, at elevations ranging from 476·95 to 491·06. The Maganasibi river was gauged at the same time in order to give the total flow at Deux Rivières.

Summary of measurements for the Ottawa river:—

Mouth of the river	26
Carillon	4
Besserer's Grove	16
Chaudière falls	49
Above Ottawa	4
Calumet channel	3
Gower Point	4
Below Allumette island	3
Culbute channel	3
Above Deux Rivières	11
	123

A synopsis of the current meter measurements of the larger tributaries of the Ottawa river is as follows:—

SOUTH TRIBUTARIES.

La Graisse River.

Two current meter measurements were made in 1905 at high and low water from railway bridge at Rigaud.

The gauge is on a pier above MacDonald's upper dam.

South Nation River.

Two current meter measurements were made in 1905 at high and low water, the former from the Canadian Pacific railway bridge and the latter by wading.

The gauge was placed on Mr. Hagar's dam at Plantagenet Mills, and has been tied into the precise levels. In April, of 1907 part of the dam together with the gauge was carried away by a freshet. On May 23, 1908 another gauging was taken on this river from the Canadian Pacific railway bridge near Plantagnet.

Rideau River.

Three current meter measurements were made in 1905, and one in 1908, the Grand Trunk railway bridge being used for all.

The gauge was placed on the old highway bridge known as Hurdman's, which structure has since been destroyed.

Mississippi River.

Four current meter measurements were made of this river in 1905, and one in 1908, from the highway bridge at Galetta.

The gauge was placed on Mr. Whyte's dam This dam has since been removed, but a bench mark remains that was connected with the gauge.

Madawaska River.

Four current meter measurements were made of this river in 1905, and three in 1908, from Wallace bridge, three miles west of Arnprior.

The gauge was placed on the up-stream side of the highway bridge and dam at McLachlan's mills, and has been tied into the precise levels.

Bonnechère River.

Three current meter measurements were made in 1905, and one in 1908, from C.P.R. bridge at Renfrew.

The gauge is placed at the head of the intake of the Renfrew Power Company's plant, and has been tied into the precise levels.

Muskrat River.

Three current meter measurements were made of this river, two from the Mary Street bridge, which is about one-half mile above its mouth, and one about seven hundred feet below the mouth of the Indian river, using a boat and cable for the latter.

The gauge is on the west side of the dam, near the head-gate. It has been tied into the precise levels.

Petawawa River.

Five current meter measurements were made of this river about one-half mile above its mouth, a boat and cable being used.

The gauge is placed on a side pier above the C.P.R. bridge and tied into a bench mark on the east shore of the river.

NORTH SHORE TRIBUTARIES.

North River.

Three current meter measurements were made of this river at a section about 2½ miles above St. Andrews, one in 1905 and two in 1907. A boat and cable were used for all these measurements.

The gauge was placed on the down-stream side of a pier about one-quarter of a mile above Mr. Walsh's dam, but is no longer in existence. The bench mark still remains.

Rouge River.

Two current meter measurements were made of this river in 1905, about Blackburn rapids and about one mile above Ross' power plant. On May 29, 1908, a metering was made at Johnson's ferry. A boat and cable were used for all.

The gauge was placed on the up-stream side of the east abutment of power dam, and tied into a bench mark cut on a rock.

North Nation River.

Two current meter measurements were made in 1905, and one in 1908, from the highway bridge near Plaisance.

The gauge was placed on a pier above the dam at North Nation Mills, about 3 miles above the gauging section, and tied into a bench mark.

Blanche River.

Two current meter measurements were made in 1905, and one in 1908 from the C.P.R. bridge, about two and one-half miles west of Thurso.

A gauge was placed on the down-stream side of the centre pier of the highway bridge about two and one-half miles west of Thurso.

A gauge was placed on the down-stream side of the centre pier of the highway bridge just below Black's grist mill, and tied into a bench mark on the west shore of the stream.

Du Lièvre River.

Three current meter measurements were made in 1905, about one-half mile above Buckingham, opposite the saw-mill. A metering was made in 1908, 5 miles above Buckingham, near Newton's place.

A gauge was placed on one of the piers supporting the slide between the two falls at Buckingham and tied into a bench mark on the west shore of the river.

Little Blanche River.

Two current meter measurements were made, one from Mitchell's bridge, two miles east of East Templeton, and the other 400 feet above the bridge.

A gauge was placed above the dam on the east shore at Ste. Rose de Lima, and tied into a bench mark.

Gatineau River.

Sixteen current meter measurements were made, thirteen below Ironsides, one of the Desert river at Maniwaki, one of the Gens de Terre river near its mouth, and one of the main Gatineau, three and one-half miles above the Gens de Terre river.

A gauge was placed on the old bridge at Chelsea, and tied into the precise levels, and is still in existence.

Quyon River.

One current meter measurement was made with an accoustic meter from the foot bridge, and about one quarter of a mile below Dowd's mill.

A gauge was placed on the up-stream side of Dowd's dam on the east shore of the river and tied into a bench mark.

Coulonge River.

Four current meter measurements were made from the Canadian Pacific railway bridge over this river. An acoustic meter was used for one and for the rest a large Price meter.

A gauge was nailed on the N.E. side of the pier between the main dam and the log slide at High Falls and tied into a bench mark.

Black River.

Five current meter measurements were made of this river from the highway bridge at Waltham, one with an acoustic meter and the other four with a large Price meter.

A gauge was firmly secured to the west bank and tied into a bench mark. bridge and tied into a bench mark.

Du Moine River.

Three current meter measurements were made of this river, and one approximation was obtained in the spring of 1905 with floats, at a section a little over a mile from the mouth.

A gauge was firmly secured to the west bank and tied into a bench mark.

Maganisibi River.

Seven current meter measurements were made of this river from the highway bridge about one mile above its mouth, one with an acoustic meter and the rest with a large Price meter.

A gauge was placed on the down-stream side of the west abutment, and tied into a bench mark on the opposite shore.

Total number of current meter measurements:—

Main Ottawa river	123
Southern tributaries	33
Northern tributaries	54
Mattawa river	103
Amable du Fond river	128
French river	44
Total	484

Excepting where otherwise mentioned, a large Price current meter was used.

The results of these gaugings are given in tables included in the report by the hydraulic engineer, and are shown graphically on plates 25, 26, 28, 29, 30, 54, 55 and 56.

PRECISE LEVELLING.

In organizing the field force for the survey of the Georgian Bay Ship canal route, the formation of a field party for the determination of a common plane of reference for the different sections of the survey, to which all elevations could be referred, was naturally of primary importance.

As the work on the several sections of the survey, extending from Montreal to Georgian Bay, a distance of 440 miles, commenced at the same time, it was impossible to initiate the levelling on the different sections from a common datum, and each party had to assume a convenient and arbitrary plane of reference for preliminary levelling until such time as it would be possible to connect their net of elevations to a common line of precise levelling.

For a work of such magnitude as that of the proposed waterway, it was at once recognized as a necessity that a precise level party be formed independently of all other parties, to check finally the transfers already made of the U. S. Coast and Geodetic determinations to our territory and carry on the same system all along the route under survey.

This work was placed under the charge of Mr. Chas. F. X. Chaloner, C.E., who had been doing geodetic levelling for the Department of Public Works for many years, under the direction of Mr. R. Steckel, C.E., and certainly no better man could have been secured to undertake the work, which required extreme accuracy and great experience.

The programme carried out was the immediate transfer of the elevation of the Coteau Landing bench mark as determined for the Soulanges Canal to section No. 1 of the survey; check lines from the U. S. Coast and Geodetic bench mark at Rouses' Point, N.Y., to Coteau Landing and Cornwall; main line from Montreal to North Bay, thence to the mouth of the French river and check line from Toronto to North Bay with branch lines at different places, in all 945 miles of levelling.

In conjunction with this, automatic gauges were placed at Toronto, Collingwood and French River harbour to collect the necessary data for checking precise level lines by water level transfers from U.S. permanent gauge stations.

All the elevations shown on plans are, therefore, based upon the 'Greenbush' bench mark, Governor's island, New York, the accepted elevation of which, since a readjustment in 1903, is 13·863 above mean sea level.

The initial point upon which our system of levels depend is a cross cut on top of plinth course, north end of the Chapman building at Rouses' Point, Clinton county, in the State of New York. The elevation of this bench mark is derived from a readjustment made in 1903 by the U.S. Coast and Geodetic Survey, and is now accepted as 107·955 above mean sea level, instead of 110·06 as used formerly.

All the details relating to the precise levelling and water level transfers made in connection with this survey, with results, adjustments, a descriptive list of permanent bench marks established with their elevations, &c,, will be found in a separate report under the title 'Georgian Bay Ship Canal Survey,' 'Precise Levelling.' This special report is accompanied by a map showing the routes followed by the precise level party, as well as other lines made by the Canadian Deep Waterways Commission, by Mr. Steckel for the Department of Public Works and by the late Mr. Munro in regard to the Soulanges canal for the Department of Railways and Canals.

TEST BORINGS.

As soon as the work of the different survey parties was well under way, the question of test borings was considered, and the formation of three special boring parties, under the direction of an experienced engineer, was deemed advisable.

Though the sectional engineers were instructed to note the character of the ground, when necessary, it was not thought in the best interests of the survey that they should be charged with the test borings, as this would have a tendency to delay the work of taking topography, soundings, contours, &c.

Consequently, boring parties were formed, to be directed from head-quarters as the general lines of the project developed, and in accordance with decisions reached from time to time to investigate more closely main and alternative routes, trial lines and dam and lock locations.

The boring parties, which were composed of an assistant engineer, foreman and three or more labourers, were placed under the direction of Mr. A. R. Dufresne, Mem. Can. Soc. C.E., one of the departmental engineers.

Mr. Dufresne remained in charge until the end of February, 1906, when he was appointed resident engineer at Winnipeg, Manitoba, for the department. He was succeeded by Mr. H. M. Davy.

Three boring machines were purchased of the type known as the 'Pierce Test Boring apparatus No. 80.'

This boring machine consists essentially of an outer pipe or casing, two inches in diameter, and an inner pipe or drill, three-fourths of an inch in diameter, with appliances for forcing them into the ground. Water is forced with a hand-pump, down the smaller pipe, and comes up between the two pipes, carrying with it in suspension the material through which it passes.

Test borings were made in or near the proposed channels, at the dam and lock sites, and all locations investigated for the proposed waterway from Bout de l'Ile (Montreal island) to Lake Nipissing.

When possible, the boring machines were used, but where boulders were in evidence it was necessary to dig test pits, as the machines could not be used satisfactorily in boulder material. The use of dynamite, however, was resorted to in many cases with considerable success in connection with the boring machines for loosening hard material or for breaking occasional boulders.

In soft material under water, or in swamps, hollow rods, pointed at one end, were used.

Considerable difficulty was experienced in a great many localities where boulder drift material was encountered under water, or in low places where test pits could not be kept dry owing to seepage water.

Generally, the first two borings made in any locality were spaced 400 feet apart. If the material penetrated gave indications of being very regular, they were spaced farther apart. For dam and lock sites, borings were made closer together.

In many cases, the result of the borings was such that the line of the canal on the sites selected for structures had to be changed on account of the unfavourable foundations encountered, and new lines or sites investigated.

Borings were carried deeper than the proposed grade of the 22-foot channel or to bed rock, if encountered above grade; for lock sites to bed rock, when possible, and for dams and embankments to bed rock or hard stratum. Bed rock was not penetrated, as no diamond drills were used.

Samples of the different classes of material at each boring were taken and kept in properly labelled bottles for future reference.

Nearly all the borings taken are shown on the general plans and are designated by a red circle bearing the same number as a vertical section of the boring, giving the character, thickness and depth of each stratum.

The total number of borings made was 2,990, with a total depth of 27,000 feet.

No borings were made on the French river as practically only granite is encountered there.

The characteristic feature of the test boring investigation throughout the Mattawa and Summit sections was the presence of extensive boulder drift formation on the surface, which necessitated considerable test pit excavation. The only locality in which there is an absence of this boulder drift is through a swamp on the Lake Nipissing-Trout lake line, adjoining Lake Nipissing. Some hard pan was encountered but rock of the granite-gneiss variety crops out almost everywhere.

Most of the localities tested in the Ottawa district have shown rock generally above grade, some gneiss being encountered in the western end, and limestone from Des Joachims east. Other characteristic materials encountered are sand, clay or a mixture of sand and clay.

Most of the borings taken in the beds of rivers were made through the ice, excepting on Lake St. Louis, where they were taken from a scow, especially fitted for this work, and which was kindly loaned by the Hydrographic branch of the Marine and Fisheries Department.

A complete record of the borings made, with their results, is given in Appendix B, being a detailed report prepared by Mr. H. M. Davy, the engineer in charge of the test borings. Moreover as mentioned above, most of the borings are illustrated on the large scale maps, giving their location and the different strata penetrated. Much of that information is condensed in the reports from the district engineers, and it is unnecessary for me to go into further detail. Enough has been given to show that the test borings required have involved an enormous amount of work, naturally of a comparatively expensive nature. But they were necessary to arrive at an intelligent and satisfactory estimate of cost. In case construction is undertaken, before the contract plans for the different structures can be prepared, a great many more borings will be required.

SUPPLEMENTARY SURVEYS.

From time to time during the preparation of plans and the gradual development of the best possible project for the waterway, small parties were detached from the office staff to obtain supplementary information at critical points, where it was proposed to place structures, and in cases of radical changes in the alignment. These parties generally consisted of an engineer in charge, one assistant and three to four labourers. They were out only for a few days at a time collecting additional information as to topography, contours, character of the material, &c. During the autumn of 1906 as the water on the Ottawa river was very low, a detailed survey of the Chaudière falls, including the lay-out of all the works connected with the different industries established there, was made in order to have this most important part of the river as complete and accurate as possible.

In order to give permanent value to the field work done in connection with the survey, it was decided, during the spring of 1906, to form a small party with Mr. L. R. Voligny, in charge, to fix a few geographical points along the route, in order to check finally the work done by the different surveying parties and to show on the final plans the territory surveyed in its proper geographical position.

In performing this work the party was instructed also to replace some of the main traverse or triangulation stations by permanent monuments or marks, this to be done principally in the vicinity of the location of proposed structures and in such a manner that these stations could be easily found later and the survey retraced for some distance from these points, when so required for construction purposes. Whenever possible, Mr. Voligny was also to tie in any well defined township lines with the survey system.

At North Bay, the Chief Astronomer's observation pier was located and an observation for azimuth taken, fixing that part of the survey in its correct geographical position. The township line between Ferris and Widdifield was located and connected with our survey net.

All sections and subsections of the survey between North Bay and Montreal were tied together and observations for azimuth taken at each end. The results of these observations when compared with those of the several sectional engineers were found to agree within limits of permissible error.

Sites for observation piers to be occupied by the Chief Astronomer of the government service, were chosen at Mattawa and Pembroke and fixed with respect to the survey. At Montreal, connection was made with the Hydrographic Survey of the

St. Lawrence river by triangulation, thereby forming a continuous survey from Georgian Bay to Quebec.

A traverse from Balmer's Bay to Chalk River, seven miles long, was made to connect the observation station at that point. This was necessary to fix the geographical position of the river between North Bay and Ottawa, the co-ordinates of Pembroke occupied during the summer of 1906 by the Chief Astronomer not being available.

Permanent reference points were put in at all dams and lock sites along the route between North Bay and Montreal.

Whenever possible township lines were connected directly with the survey lines. When this was impossible, well defined farm or lot lines were picked up at convenient intervals from which the townships were placed on the original plans. A few lines on each section were checked by careful measurements for accuracy of chainage and in no case was a serious discrepancy found.

In fact, this check demonstrated that the survey had been performed in a thorough and efficient manner and was in every way creditable to the sectional engineers and their assistants.

GENERAL RECONNAISSANCES AND EXPLORATIONS.

From the beginning of the survey, arrangements were made for systematic and progressive reconnaissances in advance of the surveying parties, in order to better direct the field work, and limit as much as possible the territory to be placed under development.

It was understood that the district engineers should be acquainted, not only with conditions and physical features of the territory within the limits of their districts, but should investigate the entire route in order to be able to act in consultation on all matters referring to this project.

Therefore, from time to time the different parts of the proposed waterway were examined, alternative routes were thoroughly explored, and preliminary deductions made, upon which supplementary instructions to the survey parties were based, either extending or limiting their work.

The French river, the different routes leading from Lake Nipissing to the Summit level, the conditions at the Summit, the Mattawa river valley, and all critical points on the Ottawa river were carefully examined by myself, in company with the district engineers, and all possible combinations of raised water surface, canal alignment, location and character of structures, &c., consistent with economy, were discussed and noted for final determination, and several visits had to be made to study the conditions on the ground as the survey proceeded.

GENERAL REMARKS.

The extent and difficulties of the survey were not fully realized until the field force had commenced their work and reconnaissances had been made over the entire route. The distance of 440 miles to be covered from Georgian Bay to Montreal was increased to over 600 miles by reason of the several branches of the Ottawa river, which had to be developed, and the several alternative routes which had to be inspected. In many places the strip of territory under investigation was much over one mile in width, with very wide stretches of water, which had to be covered closely by soundings and the bottom tested by borings.

Work had to be performed frequently on very rough and dangerous waters, and extreme care had to be exercised to prevent serious accidents. That the survey was completed with only two drowning accidents, which occurred near the close of the work, speaks very highly for the good organization and the careful methods of the engineers in charge of parties. In order to reduce the danger of accidents, the prin-

ciple was adopted at the start of the work that all the equipment should be new and the best available.

Consequently, special boats, of ample strength and safety, were ordered to be built according to our specifications.

Each party was provided with the following boating equipment:—2 lumberman's boats, 36 feet long; 1 punt, 24 feet long; 1 skiff; 1 large Peterborough canoe; and 1 light canoe for portaging, &c.

On some of the sections, where relatively large bodies of water existed, it was found advantageous to have small gasoline launches, which saved much time when the work was several miles from the camping place. They were also used to transport supplies, to tow the smaller boats required by the sub-parties operating at different points, &c.

These launches were 24 feet in length, 6 foot beam, and could carry 15 men safely. They were built especially strong with a view of decreasing as much as possible the chance of accidents, such as striking logs or rocks, a very common occurrence in shallow waters.

In order that the work might proceed as rapidly as possible, the parties were arranged so that they could be subdivided and the levelling, topography, contours and soundings carried on at the same time.

To render this possible each party was well equipped with instruments, and the following were issued to each:—2 transits with stadia and other attachments, 1 Y level, 1 Dumpy level, 2 field glasses, 2 box sextants, 1 prismatic compass, 1 hand level, rods, chains, sounding wires, and all necessary articles of stationery.

The camp equipment generally consisted of:

One engineer's tent.
One tent for rodmen and chainmen.
Two large tents for the men.
One dining-tent.
One small tent for provisions.
One small tent for the cook.

All these were supplied with fly, tarpaulin, folding tables, stoves, &c. In many cases an extra tent was issued to be used as a drafting office. All camp beds, blankets, cooking utensils, &c., were issued from head-quarters, when the survey was organized.

Great care was exercised to supply everything needed, in order that the work might not be retarded for want of equipment and appliances to carry on the survey successfully and with despatch.

The ordinary survey methods for similar work were followed and need not be described here in detail. They were governed by a complete set of rules and instructions, as given in Appendix A, these being supplemented from time to time to meet special conditions.

In general, all investigated areas were covered by accurate triangulation or closed traverse or both as a primary net upon which the topography, soundings and other detailed information were based.

Base lines, incorporated in the above-mentioned net at suitable intervals in each section, were carefully measured by steel tapes with spring balance and thermometers —tapes previously tested for temperature and tension—the line levelled, reduced to the horizontal, and correction for tape error applied for, &c.

Meridians were established by observation on Polaris or some other circumpolar star at elongation and connected with the survey system.

The true azimuth was carried throughout the main triangulation or traverse for closure with adjustment of error between carried and observed azimuth, after correction for convergence of meridians, &c.

Where triangulation points were first established, the customary method of connecting the triangulation stations was used, starting from a station with known

azimuth to another visible triangulation station meandering for positions required and the circuit closed by stadia or chainage on the next main station.

Work on both shores of the rivers was closely connected by cross-river sights, and shore line stations served to unite topography and hydrography. Check levels were carefully carried early in the survey in duplicate lines from the assumed elevations of permanent benches at each end of every section, which were connected with the precise level line as soon as available and the levels reduced to their true elevation above mean sea level.

The topography was generally obtained from subsidiary lines and chain or stadia measurements. But in many cases owing to the extreme roughness of the territory, and the high underbrush, this information was obtained by means of hand levels, rods and tapes with angle mirrors or box sextants, for direction, excepting in those cases where possible structures might be located, when they were always more closely cross-sectioned by transit and Y level.

Where the shores were very precipitous, either a limiting contour traverse line was run, or the slope, if it were a quick one, was determined roughly from shore stations by approximation, as no interests could be affected by a raised water surface.

When possible the stadia method of surveying was used in mapping contours and general locations.

Particular localities where required were covered so as to enable them to be developed in 2 and 5-foot contours.

The work during winter time consisted principally in taking soundings from the ice, as it permitted of greater accuracy and required less office work for plotting on plans.

For this work each party was supplied with a boring machine consisting of an auger geared to a hand wheel mounted on a sleigh and capable of drilling a 4-inch hole through 36 inches of ice. In some cases, however, the use of ice chisels was necessary.

The lay-out for the ice borings depended on the depth of water, reference being made to the elevation of the proposed water level. In shallow places where excavation was likely to be required, lines were laid out 100 or 200 feet apart, and soundings across taken every 50 or 100 feet. In deep water where the bottom of the rivers or lakes was 30 feet or more under the proposed regulated surface level and of regular depth, lines were laid only every 500 or 1,000 feet until shallow water was again reached. This was done in order to reduce the cost of the work. All soundings could not be made from the ice on account of the large areas to be covered, and of unsafe ice in many localities due to strong currents, &c. Recourse had therefore to be made to boats and the use of the sweep bar.

In very swift rapids no unnecessary risks were taken, and depths were estimated after careful observations of all conditions, especially when no close survey was required in connection with proposed structures.

In taking soundings the man in charge was instructed to carefully note the nature of the bottom,—independently of the special boring parties organized for that purpose—also the convenient location of all such material as would prove valuable in construction.

With regard to borings, instructions were issued to the sectional engineers to prepare plans, showing the location and number of borings desired in any particular locality, for the guidance of the engineer in charge of the boring party and his assistants.

At all critical points, high water marks of previous years, and the highest on record when obtainable from inhabitants, were carefully noted while records of the water levels were kept continuously for use in hydraulic deductions.

As the work progressed, plotting on the plans was carried on by the field staff with a view of proving every day the accuracy of the triangulation and traverse

systems and in order to be careful that any area or location under consideration received the necessary investigation.

The survey as briefly sketched in the preceding pages was carried out under many difficulties which necessarily caused unexpected delays.

During the first winter of the work (1905) the weather conditions which prevailed were very unfavourable. Extreme cold, and heavy snowfalls retarded the field work very materially. The men suffered many hardships and progress at times could only be very slow.

During winter time, it was very inconvenient and often impossible to follow the work with the camp, especially in a sparsely settled district, and the distance to and from work was sometimes considerable. The winter of 1905 was remarkable on account of the prevalence of high winds and drifting snow, making the roads almost impassable.

Nearly every day the roads had to be opened through 1 or 2 feet of snow which rendered travelling very difficult and caused a great loss of time. On the lakes and rivers, water overflowing the ice under the deep snow, created the worst possible conditions for sounding work.

In the bush the snow was exceedingly deep and fine, which hampered the men while snowshoeing.

The work, however, was always prosecuted with the greatest good-will and the men deserve great credit for making fair progress under such trying conditions. The cost was necessarily increased and the completion of the survey delayed, but this was unavoidable.

During the summer of 1905 substantial progress was made and most of the land work completed.

In the fall of 1905 it was hoped that the conditions would be favourable to rush on the ice the soundings of several long stretches of river and so complete them early in the winter. But again nature did not co-operate with the arrangements planned, for under ordinary conditions, ice forms in November. But the fall of that year was unusually mild and the ice was not safe for sounding operations until late in December, and then only for a few days, as a thaw occurred, which further delayed the work.

The different parties, however, did their utmost to push the work and show satisfactory progress. The engineers and their men were out in all kinds of weather and did not spare themselves to obtain good results and carry on the work as economically as possible. As a general rule, the men worked 10 hours per day, exclusive of leaving and returning to camp.

The labourers were under the charge of an experienced foreman, who was in every case an expert guide and riverman. To him was entrusted the handling of boats in dangerous waters, and to this is probably due the total absence of drowning accidents during the two years of the survey proper.

After the completion of the field work, part of the engineering staff was retained to do plotting on plans, to make computations, take quantities, &c., at the offices in Ottawa. Some of the engineers were transferred to other branches of the government service and others engaged with private concerns.

MINUTES OF BOARD MEETINGS.

As previously mentioned, when the survey was organized it was the intention to create an Advisory Board of Engineers. This board to consist of the chief engineer of the department, the engineer in charge of the survey and the three district engineers.

The matter was left in abeyance for various reasons and no board was officially appointed.

The great benefits of such an organization were, however, recognized by all the officers at the head of the work, and though not officially constituted, the functions of a board were carried out in practice, as far as possible. As executive officer, I arranged from time to time, meetings at which the chief engineer, the district engineers and myself were present, for the discussion of all important questions affecting the proposed undertaking. Apart from these general discussions, the details of the project, problems involved, determination of unit prices to be applied to quantities, &c., &c., the district engineers were always in constant consultation with me and a decision given only after full discussion and the most mature consideration. Frequently, some of the sectional engineers having had considerable experience on some of the questions under discussion were invited to state their opinions.

When doubt existed as to the advisability of reaching a conclusion without further investigation, visits to special works were made and the experience of other engineers inquired into.

In this way the plans presented and the conclusions of the report, are the result of the deliberations of several experienced engineers who have not spared themselves in endeavouring to make the lines and details of the project accord with the best modern practice.

The first meeting was held on October 13, 1904, after the different survey parties had fairly commenced their field work.

Questions relating to the survey, levels, borings, and field plans were submitted for discussion, and the following decisions were agreed upon:—

Surveys.—Connected traverse both sides of the waterways, not more than three miles in each net, to be astronomically checked not more than ten miles apart; shore lines to be contoured 25 to 50 feet above water surface. Where river or country too wide to connect shore traverses, triangulations with closed traverses between triangulation stations to be made.

Permanent stations to be established along shore, upon which to base soundings, &c., later.

Levels.—Decided to have sectional engineers carry levels over sections in advance of other work, also to have Mr. Chas. F. X. Chaloner, departmental engineer, report at Ottawa to organize a party for precise levelling.

Borings.—Decided that ordinary jump or test bars be used by each section, where possible, and that at a latter date to organize separate parties to investigate particular localities, where structures were likely to be built, with suitable boring machines.

Plans.—Field plotting to be kept up with field work and not to be limited to any regular sized plans.

After that date several inspection trips to different points were made and on March 16, 1905, another meeting was held to discuss matters relating to plans, and to flow measurements.

Many details relating to size and scale of working plans and maps to be published were settled. It was decided that soundings should be shown in elevation above mean sea level, the same as all land levels. A method of showing topography and hydrography, defining the contours, &c., was adopted.

Regarding the gauging of flow, the formation of special gauging parties was considered necessary and instructions issued for their immediate organization.

It was decided that the district engineers should determine the critical sections of the main river where measurements should be taken and define them , and that the hydraulic engineer be then instructed where to gauge the flow; all locations and lay-out of the cross-sections in connection with the gauging of the main river tributaries to be made by the hydraulic party.

Regarding tributary streams, a reconnaissance of these to be made and a report given on each as far from their outlet as may be determined by the district engineers.

At several subsequent informal meetings, much discussion took place as to locks, types of dams, regulating works, &c., and it was decided as very advisable, to visit some works of river improvements in this country and in the United States before arriving at conclusions on some of the matters under consideration.

On April 5, 1905, the Canadian lock at Sault Ste. Marie was visited and a splendid opportunity was given to inspect the entire structure as it had been pumped dry for painting and repairs.

The next day the American locks were inspected, and the large Poe lock was also seen empty. Valuable information was obtained from Superintendent Boyd of the Canadian lock, from Mr. Ripley, Superintendent of the American locks and from Mr. L. C. Sabin, his assistant.

The 'Stoney' sluices on both the Canadian and American sides were visited and their operation inquired into.

On the 7th of the same month through the courtesy of Mr. George B. Wisner, the regulation works of the Chicago Drainage canal, at Joliette, Illinois, were seen. The working of the bear trap dam, 160 feet in length was kindly explained by the superintendent and operated for our benefit. There was also a space controlled by Stoney sluice gates and the difficulties experienced in their manipulation as well as probable causes were carefully noted.

The following day was spent in investigating the lift bridges as built on the Chicago canal and Mr. Wisner was very kind in giving us valued information in this connection.

Various other canal works were also visited before returning to Ottawa.

In July of the same year, I attended with Mr. Coutlee, a meeting of the International Waterways Commission at Montreal, and we had an opportunity of discussing thoroughly many questions relating to canal work with the late George Y. Wisner, C.E., who had been intimately connected with the Deep Waterways Commission of 1901, and who had also been a consulting engineer for the Montreal, Ottawa, and Georgian Bay Canal Company, during the same year.

About the same time the St. Lawrence canals were visited, where an opportunity was offered to collect data for further discussion as to the suitability of concrete for lock construction, workings of 'Stoney' sluice gates, operation of lock-gates by electricity, bank protection, &c.

At the beginning of September, 1905, after having formulated a general plan of improvement for the French, Mattawa and Ottawa rivers, a canoe trip was arranged to travel these waterways, including alternative routes, in order to thoroughly grasp the ensemble of the project, to view each critical point, and to ascertain the conditions which would limit or alter the nature of the improvements contemplated. On that trip I was accompanied by Messrs. Coutlee and Chapleau, and by Mr. Alexander McDougall, hydraulic engineer, on that portion of the journey relating to the Summit level and the French river. Every possible condition of raised water surface in relation to adjacent territory, and every possible location for structures was examined and discussed. In fact all the requirements for the canal, including Summit water supply, storage of flood waters, difficulties of construction, &c., were thoroughly examined and debated and some important decisions rendered as a result.

On February 22, 1906, as the field work was practically completed, a special meeting was held; Messrs. Coutlee, Chapleau and myself being present. Details relating to office work were discussed and decided. The question of dams also came up for discussion but no decision was reached.

This meeting was followed by another on March 12, the same members as before being present.

The main questions taken up for considerations were:—

1st. Bottom width of canal, under the different conditions encountered, through heavy earth and rock cuttings, in submerged channels, &c.

2nd. Side slopes for different materials.

3rd. Increased width in curves.

4th. Maximum curvature to be allowed through restricted channels.

5th. Depth of navigable channels and depth of water on lock sills.

6th. Minimum depth of Summit level, in order to provide against the contingency of lower water, than anticipated.

7th. Size of lock chamber; minimum length and width.

8th. General lay-out of approaches to locks, when conditions are such that a general rule will apply.

9th. General consideration of question of dams and regulating works.

10th. Further surveys connected with the French river section.

A schedule of regulations in regard to work on office plans was presented and after due consideration the following decisions were reached:—

1st. That the depth of the canal be not less than 22 feet at the lowest controlled level. Reaches to be the same as lock sills.

2nd. That the bottom width of the canal be not less than 200 feet in very heavy rock cuttings, and not less than 300 feet in submerged rock cuttings with marking cribs along the sides.

3rd. That the same width prevail for earth channels, with side slopes generally 2 feet horizontal to 1 foot vertical.

4th. That on curves, sides of channel to be produced to intersection, with inside angle rounded off.

5th. That no curves be sharper than 2°, excepting in some special cases where conditions would force a sharper curvature.

Depth at Summit level and size of lock chamber were left over for further consideration.

Another meeting was held a few days later (March 24) at which the chief engineer was present. The decisions previously given were confirmed and other matters of detail discussed.

It was agreed that, if possible, it would be advisable to have Captain J. W. Norcross of the Wolvin line of large lake freighters come to Ottawa and be examined so as to ascertain his ideas of handling boat traffic, and navigation through restricted channels.

Captain Norcross was kind enough to give us the benefit of his long experience on the lakes and his views are given in Appendix O.

An invitation was extended to the officers in charge of the survey, by Messrs. Wolvin, through Captain Norcross, to take a trip on one of their largest lake freighters, where good opportunities would be offered to observe the handling of boats through the Detroit and St. Mary's rivers, and the conditions prevailing in restricted channels. For this courtesy I desire to again express my most sincere thanks.

On June 2, 1906, I went aboard the *Augustus B. Wolvin,* at the Lackawanna Steel dock in Buffalo accompanied by Mr. Coutlee; Mr. Chapleau being detained on the French river.

This steamer is 560 feet long, 56 feet beam and has a carrying capacity of 12,000 tons.

After leaving the dock, the steamer was headed through the southern entrance of the Buffalo breakwater and proceeded up the lake at the rate of twelve or thirteen miles per hour. It took one hour to back up about 1,000 feet, turn and pass through the breakwater.

The next day the boat entered the foot of the Detroit river, Boisblanc island, and proceeded through the Limekiln crossing with two freighters ahead, and one

behind, the steering of the *Wolvin* at this point being remarkable. She threaded her way up the crooked channel of the river with great ease and was constantly passing other boats to the right or left according as the down boat indicated by whistles.

Lake St. Clair and the Flats were reached shortly after noon. There are two large sweeping curves at the foot of the St. Clair river and the steamer was often within 50 feet of the bank. The down boats travel very fast as in addition to the current of the river they are obliged to maintain good steering head-way.

The United States ship canal there consists of two walls of crib-work. Through this the boats must strictly conform to regulations for speed, passing, &c. In the river itself, through boats overhaul and pass one another.

Passing out of the river into Lake Huron the boat crosses from side to side, thus working through the stiff current at the head.

Detour on the St. Mary's river was reached on the noon of the 4th, and the river was travelled up to Hay lake at the rate of nine miles per hour. All the courses in the river are not marked by ranges but the captains steer by the conformation of the shore. Cuts and bad points are, however, clearly shown, and marked by ranges and buoys.

While going up the river several dredges were at work but the *Wolvin* passed among them without difficulty. Sault Ste. Marie was reached in the evening. Immediately after rounding the rather sharp curve going towards the lock the steamer had to slacken speed as there were four boats ahead. Two of these made fast to the north pier below the Poe lock and the *Wolvin* was obliged to berth behind them. To do this the boat was stopped in mid-stream. Lines were passed to the dock and her hauling engines moved her into place, without trouble and with very little loss of time. Three hours were spent in waiting for the lock, and when we finally proceeded, it was very dark and foggy but the river was navigated with practically no trouble, boats being passed on either side. On June 5, on Lake Superior there was a thick fog all day but the boat ran at full speed and kept whistling every minute.

Duluth was reached on June 6, after a very instructive trip which showed in a very practical manner how the requirements of navigation can best be supplied in the improvement of rivers and restricted channels.

The extensive observations made during the trip and the numerous discussions on all matters relating to navigation with practical men were of the greatest value in deciding on the general lines of the proposed waterway.

During 1907 and 1908, investigations were made by the district engineers in regard to the different types of valves and gates used in locks and controlling works, leading to a selection of the most economical and efficient types as governed by the conditions met with at the different locations.

The question of dams and especially the suitability of rock-filled dams in certain structures was carefully considered, and some works were visited in the United States and Canada, so as to collect all possible data. Various types of valves and gates were seen in actual operation and dams of different character carefully inspected. Unfortunately, the time at their disposal did not permit of their investigations extending to the Ohio and other southern rivers, and to the largest ship canals in the world.

A recommendation was made about a year ago, to the effect that a board of two or three of the engineers connected with the project should be commissioned to visit some of the larger river canalization and ship canals existing or at present under construction and collect data as to the results achieved and desirable improvements gained from actual experience. No action was taken on this recommendation, but I am still of opinion that, for a work of such magnitude as the proposed undertaking—one of the largest in the world—it would be in the interest of the government before commencing construction, to commission some of its engineers to study the world's experience in the development of waterways and works connected with them.

OFFICE WORK.

The office work at Ottawa was organized by the appointment of a few draftsmen under the direction of Mr. L. A. DesRosiers as chief draftsman. Mr. DesRosiers has to his credit a large experience in the department regarding surveys and engineering works. He was well qualified for the position and has given the greatest satisfaction.

The first work undertaken was the tracing of a large number of old survey plans obtained from the Department of Railways and Canals, also the tracing of official township, parish and other plans required for reference, and compilation.

Research work was commenced by Assistant Engineer A. T. Genest, leading to the execution of special maps of the Ottawa river showing conceded lands, water-powers under option or lease, and those already disposed of, with other information of interest.

As soon as the field work had progressed sufficiently, draughtsmen were detached from head-quarters from time to time, to assist on the field plans in the plotting of triangulations, traverses, &c., in order to keep the plans advanced with the field work, in so far as necessary to effect a check on the field operations.

Sectional engineers in the field were supplied as fast as possible with copies of all township or any particular old survey plans existing, which might be of some use in directing their survey.

When the survey was completed and the engineers ordered to report at head-quarters for office work, quite a few of the plans partially plotted in the field had to be transferred to new sheets of drawing paper as some of them had been accidentally damaged by water. With the assistance of the engineers a force of draftsmen was employed completing the field plans, and making copies rearranged in suitable sections. On these plans are recorded, all elevations, contours, bench marks, the centre line of routes investigated, cuts, location of structures such as locks, dams, regulating works, &c.; ranges of lights, cross-sections of the waterway, diagrams illustrating borings, water records, flooded areas, grade contours, mileage, &c., &c.

In every case, on the same sheets is a profile showing the bottom or grade line of the proposed channels, the present water surface and the proposed water levels, the location of locks and the profile and nature of material to be excavated.

Land divisions on both sides of the route, with lot numbers have been compiled, as far as available, and also plans of adjoining cities, towns and villages.

The working plans which are made to a scale of 400 feet to 1 inch are as follows:—

No. 1.—Montreal to Ste. Anne de Bellevue.
No. 1A.—Bout de l'Ile to Lake of Two Mountains.
No. 2.—Ste. Anne de Bellevue to Hawkesbury.
No. 3.—Hawkesbury to Ottawa.
No. 4.—Ottawa to Chenaux rapids.
No. 5.—Chenaux rapids to Pembroke.
No. 5A.—Sable rapids to Fort William, Que.
No. 6.—Pembroke to Des Joachims rapids.
No. 7.—Des Joachims rapids to Mattawa.
No. 8.—Mattawa to head of French river on Lake Nipissing.
No. 9.—Head of French river to Georgian Bay.

These maps, have been prepared strictly for engineering purposes and are too large for publication. As it was necessary, however, that maps illustrating the routes selected, as well as alternative routes investigated, accompany the report for a better understanding of the physical and engineering features of the project, a second set of maps reduced to a scale of 4,000 feet to 1 inch was prepared, which is suitable for publication and which contains essentially all the information which is of general interest.

As it was required that the estimated cost of the project be as complete and as accurate as possible, general plans of all structures were made in order that correct quantities could be obtained.

Enlarged plans of dam and lock sites with contours, &c., have also been prepared.

The reduced plans from the large detailed sheets, show the route with complete profile of the land and water surface and the different reaches proposed.

Though it was impossible to show on them much of the topography and other details, they, however, show the project in a general way and give a good idea of the works required and the location of the proposed structures. From thirty-three to forty miles of river are shown on each sheet.

In addition to these, two general maps, one showing the territory adjacent to the waterways, the other embracing all of the Great Lakes have been prepared. The first, which is plotted on a scale of six miles to 1 inch, shows the general topography of the country through which the proposed waterway is located, together with a general profile of the centre line, and also serves as an index map to the large scale plans.

The second general map is for the purpose of showing all the principal railway and water routes from the head of the Great Lakes, in relation to the proposed Ottawa River Waterway, and contains several tables of comparative distances between main shipping points via different routes.

A special map of the drainage area of the Ottawa river with subdivisions showing the water-shed area of every tributary will be found of interest, and has been prepared in connection with the question of storage reservoirs for the regulation of the flood flow.

Apart from these, various plans and diagrams regarding hydraulic investigations and other special matters referred to in this report were also prepared.

The taking out of quantities for the main and alternative routes has involved a very large amount of work. This was done with the utmost care by experienced computers and carefully checked. In order that the estimated cost be as reliable and accurate as possible, all quantities referring to excavations, embankments, locks, dams, controlling works, flooded lands, &c., have been itemized and worked out in detail. In applying prices for the estimated cost, in every case, local conditions have been considered and difficulties of construction likely to be encountered, have been studied.

A limited staff was maintained at Ottawa to carry on the necessary correspondence; the supervision of accounts, the care of instruments and equipment besides performing research work, and a somewhat detailed description of this branch of the work may be of interest.

The amount of correspondence was relatively great, owing to the daily communication maintained with the field staff; to the frequent exchange of opinions with engineers in charge of similar works in the United States and in Europe; to the research work performed in connection with land grants and water-power priveleges in the territory under survey, and my departmental duties as assistant chief engineer also contributed considerably. It gives me pleasure to state it has all been satisfactorily performed by those to whom it was entrusted.

As the cardinal principal of this organization was to have the survey completed as thoroughly and rapidly as possible and at the same time, economically, all expenditures were carefully checked.

All accounts for supplies purchased in connection with the field work had to bear the following certificate 'Goods received. Prices fair and just,' followed by the signature of the engineer in charge of the party. They were included in a return of accounts compiled at the end of each month in conjunction with the pay-list and forwarded to the respective distrist engineer who wrote the certificate 'Approved' followed by his signature. They were then carefully checked by a member of the clerical staff, care being exercised to ascertain that the prices charged were

reasonable and that they had the necessary certificates. I then signed them and they were transmitted to the chief accountant of the department for payment. As mentioned previously in this report no accounting branch was organized in connection with the survey. A paymaster, however, was employed during 1905 to visit each camp every month so as to pay the engineers and men their wages in currency.

On such a large undertaking the purchase and cost of provisions was an important item in connection with the field work.

At the commencement, provisions were supplied to the field parties to last until the sectional engineers could perfect arrangements with local merchants. When dealing with the latter, I frequently cautioned the district and sectional engineers to examine and control severely all expenditures and to allow no fancy prices or the purchase of articles which might seem extravagant or unnecessary.

In order to secure uniformity among the camps and for the guidance of the sectional engineers a circular was issued giving the following ration and price list, which was based on the list which described the food necessary to subsist one man one day while connected with the United States Geological Survey parties. The prices were kindly supplied by Bryson, Graham & Co., and were the ruling market value in Ottawa at that time.

RATION LIST AND PRICE LIST.

Quantities given below are for rations for 100 men for one day. These being maximum amounts sufficient for all circumstances, are not to be exceeded.

Articles.	Quantity.	Cost.	Total Cost.
		$ cts.	$ cts.
Fresh meat	100 lbs.	0 12c. per lb.	12 00
Cured meat	35 "	0 17 "	5 95
Canned meat	10 "	0 14 "	1 40
Cheese	5 "	0 12½ "	0 62½
Lard	15 "	0 11 "	1 65
Flour	75 "	2 80 per cwt.	2 10
Crackers	5 "	0 11c. per lb. (average).	0 55
Corn meal	15 "	0 04¾ " "	0 72
Cereals	15 "	0 04¾ " "	0 72
Macaroni,	15 "	0 04¾ " "	0 72
Sago or corn starch	15 "	0 04¾ " "	0 72
Baking powder or yeast cakes	5 "	0 05½ "	0 27½
Granulated sugar	40 "	0 04¾ "	1 90
Molasses	1 gallon.	0 45c. per gall.	0 45
Coffee	12 lbs.	0 30c. per lb.	3 60
Tea, chocolate or cocoa	2 "	0 35 "	0 70
Condensed milk	10 cans.	0 13¾c. per can.	1 37½
Butter	10 lbs.	0 20c. per lb.	2 00
Dried fruit	20 "	0 12⅔ " (average).	2 53⅓
Rice	10 "	0 05 "	0 50
Beans	10 "	0 03⅓ "	0 33⅓
Potatoes or other vegetables	100 "	0 50c. per bush.	0 83⅓
Canned vegetables	20 cans.	1 15c. per doz.	1 53⅓
Canned fruit	10 "	2 00 "	1 66⅔
Spices	4 ozs.	0 03c. per oz.	0 12
Flavouring extracts	4 "	0 10 "	0 40
Pepper	¼ lb.	0 28c. per lb.	0 07
Mustard	¼ "	0 50 "	0 12½
Pickles	6 bottles.	0 25c. per bottle.	1 50
Vinegar	1 quart.	0 12½c. per quart.	0 12½
Table salt	10½ lbs.	0 01⅓c. per lb.	0 15

Total cost of rations for 100 men for 1 day .... $ 45.18
Total cost of rations for 1 man for 1 day 0 45⅙

NOTE.—Articles of food not mentioned in the above list, such as eggs, &c., can be purchased instead of articles of a similar nature which are quoted.

As will be seen in the following statement, this order was faithfully observed as the average rate for the entire field work, under canvas, was 44 cents per man per

diem. The difference in the averages was mainly due to the cost of transportation, when camps were a long distance from towns or villages.

Name of Party.	Date of Field Work.	No. of Days.	Cost of Provisions.	Rate.
			$ cts.	$ cts.
French River	May 13, '06-July 31, '06	1,352	740 00	0 54¾
Lake Nipissing	Dec. 21, '04-Mar. 31, '06	5,027	3,161 31	0 63
Section No. 1	Sept. 27, '04-Dec. 31, '05	7,227	3,568 90	0 49⅓
Section No. 2	Sept. 27, '04-Dec. 31, '05	7,676	3,615 54	0 47
Section No. 3	Sept. 27, '04-Dec. 31, '05	8,157½	3,823 09	0 47
Section No. 4	Sept. 27, '04-Jan. 31, '06	9,946	3,691 83	0 37
Section No. 4 A	Sept. 1, '05-Jan. 31, '06	2,507	1,181 33	0 47
Section No. 5	Sept. 27, '04-Jan. 31, '06	9,183	2,358 33	0 25⅔
Section No. 6	Sept. 27, '04-Jan. 31, '06	8,697½	3,344 27	0 38½
Section No. 7	Sept. 27, '04-Sept. 30, '05	7,032½	3,324 35	0 47¼
Section No. 8	Sept. 27, '04-Aug. 31, '05	6,241½	3,209 21	0 51½
Section No. 9	Sept. 27, '04-Oct. 31, '05	7,100	3,264 75	0 46
Totals		80,147	35,282 91	
Averages		6,679	2,940 24	0 44

The staff was also instructed by circular letter that accounts for travelling expenses should bear the following certificate 'The whole of this expenditure was incurred on government business,' followed by the signature of the person who had actually incurred the expenditure and then to be forwarded for payment in the usual manner, after having been certified as correct by the sectional engineer.

The circular further stated (1st) that if the whole or a considerable part of any trip could be made, going and returning over the same route in thirty days, a return ticket was to be purchased, (2nd) that any charge amounting to over five ($5) dollars was to be supported by an acquitted sub-voucher; (3rd) that no charge for books or stationery would be allowed as all such could be obtained through requisition from the government stationery office; and that no charge for board while working in Ottawa would be allowed, it being the head-quarters of the work.

Practically all the equipment purchased was ordered by either the district engineers or myself so as to curtail expenditure and to be certain that the article ordered was essential for the successful completion of the work.

Early in 1906 when the main field work was completed, public auction sales were held in Ottawa and in Mattawa and the greater part of the camp equipment was disposed of at good prices; the remainder of the equipment being stored, in good condition, at different points, for further supplementary investigations.

This responsible task was assigned to Mr. A. E. Cross, to whose zealous efforts and good judgment the success achieved therein, was wholly due.

As the department was building large works at St. Andrews Rapids, Man., and performing extensive surveys for proposed dredging at Fort William, Ont., St. John, N.B., and other places, it was deemed advisable to transfer the necessary field instruments from our work, thus avoiding their purchase elsewhere. In this connection, instruments to the value of $8,500 were transferred and credited to our appropriation.

The total cost of the survey up to December 31, 1908, was $696,066.47.

In view of the magnitude of the work performed and the many unforseen difficulties encountered it is considered that the sum expended is reasonable when compared with the results achieved.

STAFF.

The survey being inaugurated in September, 1904, under my immediate direction, a special office and technical staff had to be organized.

The following list gives in alphabetical order the names of the senior officials, with the dates of their appointments, promotions, and retirements.

Name.	Date of Appointment.	Capacity.	Date of Retirement.
Ault, H. W.	Dec. 11, 1907	Draftsman	Feb. 17, 1908
Barrett, R. H.	Sept. 27, 1904	1st asst. engineer on section No. 4	Jan. 28, 1905
Bell, H. P.	Sept. 27, 1904	Engineer in charge of section No. 2; December 31, 1905, transferred to office staff	Apr. 30, 1907
Birch, Anthony	Sept. 27, 1904	2nd asst. engineer on section No. 9	Oct. 21, 1905
Brousseau, Césaire	Dec. 3, 1904	Draftsman	....
Burgess, F. R.	Sept. 27, 1904	Rodman on section No. 1; January 31, 1906 transferred to office staff; September 1, 1906; promoted to be 2nd asst. engineer	....
Chaloner, C. F. X.	Oct. 14, 1904	Engineer in charge of precise levelling party	May 31, 1908
Chapleau, S. J.	Oct. 1, 1904	Engineer for Nipissing district; member survey board	....
Collins, J. J	Sept. 26, 1905	1st asst. engineer on hydraulic staff	Feb. 17, 1906
Côté, Maria	Sept. 10, 1904	Stenographer	....
Coutlée. C. R.	Oct. 1, 1904	Engineer for Montreal district, and after February 17, 1906, also in charge of Ottawa district; member survey board	....
Coyne, J. G. B.	Dec. 16, 1904	Draftsman	Mar. 31, 1907
Cross, Wm.	Sept. 27, 1904	Engineer in charge of section No. 3; December 31, 1905, transferred to office staff	Dec. 31, 1906
Cross, A. E.	Jan. 18, 1905	Paymaster and storekeeper	....
Davis, Florence G.	Jan. 21, 1905	Stenographer for hydraulic staff	Apr. 30, 1906
Davy, H. M.	Mar. 21, 1905	Draftsman; June 1, 1905, transferred as asst. engineer in charge of test boring party No. 1; July 1, 1906, promoted to be in charge of test borings	....
Dawson, L. M.	Nov. 14, 1904	Clerk	Sept. 30, 1905
De Chalot, F.	May 14, 1906	Draftsman	....
DesRosiers, L. A.	Dec. 17, 1904	Chief draftsman	....
Dillon, R. W.	Sept. 16, 1906	Compiler of statistics	July 31, 1908
D'Ornano, L.	June 24, 1907	Draftsman	....
Drury, H. A. K.	Oct. 19, 1904	2nd asst. engineer on section No. 6; January 1, 1905, promoted to be 1st asst. engineer; April 26, 1905, appointed engineer in charge; February 1, 1906, transferred to office staff	June 10, 1906
Dufresne, A. R.	Apr. 16, 1905	Engineer in charge of test borings	Feb. 28, 1906
Dunne, H. J.	Jan. 24, 1905	2nd asst. engineer on precise levelling party	May 20, 1907
Forward, E. A.	Oct. 1, 1904	1st asst. engineer on section No. 9; November 1, 1905, transferred to section No. 2; December 19, 1905, transferred to office staff	June 3, 1906
Genest, A. T.	Sept. 29, 1904	Asst. engineer at headquarters	....
Ghysens, A. L.	Sept. 27, 1904	1st asst. engineer on section No. 7; October 1, 1905, transferred to office staff	Aug. 31, 1906
Gingras, E.	Oct. 14, 1904	1st asst. engineer on precise levelling party	Apr. 30, 1907
Gingras, E. P.	Nov. 4, 1907	Draftsman	....
Goodspeed, F. G.	Sept. 27, 1904	2nd asst. engineer on section No. 8; September 1, 1905, transferred to section No. 4A.; January 31, 1906, transferred to office staff; May 16, 1906, transferred to hydraulic staff as 1st asst. engineer	Feb. 15, 1907
Gregory, P. S.	Dec. 9, 1907	Draftsman	Aug. 31, 1908
Griffiths, G. L.	Sept. 27, 1904	Engineer in charge of section No. 4	Feb. 28, 1905
Harcourt, R. H.	Oct. 19, 1904	1st asst. engineer on section No. 3	June 15, 1905
Harcourt, F. Y.	June 26, 1905	1st asst. engineer on section No. 3; December 31, 1905, transferred to office staff; May 13, 1906, transferred to French River party; August 1, 1906, rejoined office staff; resigned March 7, 1907; reappointed to office staff, September 28, 1907	Dec. 31, 1907
Jennings, G. T.	Sept. 27, 1904	1st asst. engineer on section No. 1; January 31, 1906, transferred to office staff; May 13, 1906, transferred to French River party	July 31, 1906
Johnson, S. B.	Jan. 23, 1905	Draftsman on hydraulic staff; May 1, 1907, promoted to be 1st asst. engineer	....
Johnson, Geo.	Mar. 28, 1905	2nd asst. engineer on section No. 5; January 31, 1906, transferred to office staff	May 31, 1907
Kellar, Louis	Jan. 11, 1905	1st asst. engineer on section No. 3; March 31, 1905, transferred to hydraulic party; May 31, 1905, transferred to section No. 5; January 31, 1906, transferred to office staff	Oct. 31, 1906
Kerrigan, H. G.	Sept. 27, 1904	Chainman on section No. 1; December 1, 1905, promoted to be rodman; January 31, 1906, transferred to office staff; May 1, 1906, promoted to be 2nd asst. engineer	Aug. 15, 1906
Kingston, J. L.	Oct. 14, 1904	Draftsman on precise levelling party	Aug. 25, 1906

STAFF—*Continued.*

Name.	Date of Appointment.	Capacity.	Date of Retirement.
Lamoureux, Jos.	June 1, 1905	1st asst. engineer on section No. 5; January 31, 1906, transferred to office staff; February 1, 1906, promoted to be sectional engineer	May 15, 1907
Languedoc, G. de G.	May 1, 1905	1st asst. engineer on section No. 6; January 31, 1906; transferred to office staff; August 1, 1906, transferred to astronomical party; November 1, 1906, rejoined office staff; June 1, 1908, promoted to be sectional engineer	....
Lesage, Royal	Oct. 18, 1904	2nd asst. engineer on section No. 9; November 1, 1905, transferred to section No. 4A	Jan. 19, 1906
Levesque, Jos. N.	Sept. 27, 1904	Rodman on section No. 8; September 1, 1905, transferred to section No. 4A.; January 31, 1906, transferred to office staff; May 31, 1907, transferred to drafting staff	June 30, 1908
Macbeth, C. W.	Sept. 27, 1904	1st asst. engineer on section No. 2; December 31, 1905, transferred to office staff	June 30, 1907
Macdonald, R. J.	Sept. 27, 1904	Rodman on section No. 9; July 1, 1905, transferred as asst. engineer in charge of test boring party No. 2.	Sept. 12, 1905
Macnaughten, C. E.	Sept. 27, 1904	Engineer in charge of section No. 8; September 1, 1905, transferred to section No. 4A.; January 1, 1906, transferred to office staff	Jan. 18, 1908
Macpherson, A.	Sept. 13, 1904	Supply clerk	May 31, 1907
Matheson, A. J.	Jan. 16, 1905	2nd asst. engineer on section No. 6; February 1, 1905, appointed as engineer in charge of section No. 4.; January 31, 1906, transferred to office staff	....
Mathewson, C. H.	Sept. 27, 1904	2nd asst. engineer on section No. 1	Jan. 31, 1906
Matte, J. E. R.	Mar. 21, 1905	Draftsman	....
Miles, E. S.	Sept. 27, 1904	2nd asst. engineer on section No. 7; October 1, 1905, transferred as 1st asst. engineer on section No. 4.; January 31, 1906, transferred to office staff	May 13, 1907
Moffet, P. E.	May 1, 1906	Draftsman	....
Murray, J. L.	Feb. 23, 1905	Rodman on section No. 4.; October 1, 1905, transferred to clerical staff	Apr. 13, 1908
McCool, M. J.	Sept. 27, 1904	Rodman on section No. 6; February 1, 1905, promoted to act as 2nd asst. engineer; January 31, 1906, transferred to office staff; August 1, 1906, transferred as 2nd asst. engineer on astronomical party; November 1, 1906, rejoined office staff	Mar. 14, 1907
McDougal, A. J.	Sept. 27, 1904	Engineer in charge of section No. 1; January 31, 1906, transferred to office staff; May 13, 1906, transferred as engineer in charge of French River party; August 1, 1906, rejoined office staff	May 31, 1907
McDougall, Alexander	Sept. 27, 1904	Engineer in charge of section No. 6; January 1, 1905, appointed special hydraulic engineer	Jan. 11, 1907
McLennan, A. L.	May 16, 1905	1st asst. engineer on hydraulic party	Sept. 30, 1905
O'Kelly, O. G.	Feb. 11, 1905	Rodman on Lake Nipissing party; August 31, 1905, promoted to act as 2nd asst. engineer	Mar. 31, 1906
O'Meara, A. P.	Jan. 6, 1905	Rodman on section No. 4.; January 31, 1906, transferred to office staff; April 30, 1907, transferred to drafting staff	....
O'Regan, O. G.	Nov. 1, 1904	Clerk	Nov. 11, 1905
Ouimet, S.	Oct. 1, 1904	2nd asst. engineer on section No. 4.	Nov. 30, 1905
Parent, J. H.	Sept. 27, 1904	1st asst. engineer on section No. 5; March 9, 1905, transferred to section No. 4	Jan. 31, 1906
Patton, J. N.	Sept. 6, 1905	Asst. engineer in charge of test boring party No. 2; November 18, 1905, transferred to section No. 4A.	Jan. 19, 1906
Pense, E. H.	Sept. 27, 1904	2nd asst. engineer on section No. 2; December 31, 1905, transferred to office staff; May 13, 1906, transferred to French River party; July 1, 1906, promoted to be 1st asst. engineer	Feb. 28, 1907
Perreault, E. E.	Sept. 27, 1904	Engineer in charge of section No. 7; September 30, 1905, transferred to office staff	....
Peters, F. H.	Dec. 21, 1904	Engineer in charge of Lake Nipissing party; March 31, 1906, transferred to office staff; resigned February 28, 1907; May 13, 1907, appointed to make reconnaissance of head-waters of Montreal river; August 4, 1907, rejoined office staff	June 5, 1908
Philp, D. H.	Mar. 20, 1905	2nd asst. engineer on section No. 4.; January 31, 1906, transferred to office staff; June 1, 1907, promoted to be 1st asst. engineer	....
Poulin, A. S.	Nov. 15, 1904	Clerk	April 21, 1907
Rainboth, E. J.	Sept. 27, 1904	Engineer for Ottawa district; member of survey board.	Feb. 6, 1906
Robert, A.	Sept. 27, 1904	Engineer in charge of section No. 5	Jan. 31, 1906
Robertson, H. H.	Sept. 27, 1904	2nd asst. engineer on section No. 5; March 11, 1905, promoted to act as 1st asst. engineer	Jan. 31, 1906
Sabourin, A. G.	Jan. 23, 1905	Draftsman; February 13, 1906, transferred in charge of test boring party No. 3; June 30, 1906, transferred to office staff	Feb. 28, 1907
Smith, F. R.	Sept. 27, 1904	2nd asst. engineer on section No. 3; December 31, 1905, transferred to office staff	Sept. 30, 1906

STAFF—*Concluded.*

Name.	Date of Appointment.	Capacity.	Date of Retirement.
Smith, Alice	May 1, 1906	Stenographer for hydraulic party	Dec. 31, 1906
Somerville, J. M	Oct. 1, 1904	Secretary of survey board	
Surveyer, Arthur	Sept. 27, 1904	1st asst. engineer on section No. 8; September 1, 1905, transferred to section No. 4A.; January 31, 1906, transferred to office staff	
Voligny, L. R	Sept. 27, 1904	Engineer in charge of section No. 9; October 31, 1905, transferred to office staff; July 31, 1906, appointed as engineer in charge of astronomical party; November 1, 1906, rejoined office staff; July 1, 1907, again in charge of astronomical party; September 1, 1907, rejoined office staff	Aug. 31, 1908
Walsh, J. E	Apr. 20, 1905	Recorder for hydraulic party	Dec. 31, 1906
Warner, W. G	Sept. 27, 1904	1st asst. engineer on section No. 6; January 1, 1905, promoted to act as engineer in charge	Mar. 31, 1905
Whitney, P. B	Sept. 27, 1904	Chainman on section No. 2; February 1, 1905, promoted to act as rodman; January 1, 1906, transferred to clerical staff	

Since the completion of the main field work, Messrs. Matheson, Voligny, Peters, Perreault, Languedoc, Burgess and Davy, have been frequently detached from this work and commissioned to execute surveys required in connection with proposed dredging, &c., for the department.

The salaries paid to the different grades of officials were as follows:—

Clerical staff, $50 to $150 per month; draftsmen, $105 to $135 per month; engineers in charge of sections, $200 to $225 per month; 1st assistant engineers, $150 to $175 per month; 2nd assistant engineers, $110 to $135 per month; rodmen, $75 to $90 per month; chainmen, $60 to $75 per month; foremen, $2 per diem; cooks, $2 per diem; labourers, $1.50 per diem.

CHARACTERISTICS OF THE ROUTE AND PROJECT.

The proposed Georgian Bay Ship canal is essentially a river and lake canalization scheme, and utilizes natural waterways which fortunately exist almost all the way, in practically a continuous line from Georgian Bay on Lake Huron, to Montreal, the most inland and most important of the Canadian ocean ports. By referring to the transportation map published with this report, it will be seen that a straight line struck through Montreal and Sault Ste. Marie has a direction almost due east and west, and follows closely the Ottawa river and Lake Nipissing waters, giving the most direct and shortest route from Lake Superior to a sea port. A glance at the map shows that this route, if it can be made safely navigable for large lake freighters, should be the natural outlet for all commerce of the west seeking transportation through Lakes Superior and Michigan to the nearest ocean port.

Of the 440 miles of projected navigation betweeen Georgian Bay and Montreal, from 410 to 420 miles follow the course of some river or lake.

For that part of the route from Georgian Bay to the height of land separating the watersheds of the Ottawa river and the Great Lakes, a distance of 81 miles, the French and Pickerel rivers and Lake Nipissing are utilized. From Lake Nipissing, through the height of land, for a distance of 3½ miles, the route is an artificial waterway, with the exception of a few small lakes through which it is located.

This artificial cut leads into Trout lake, thence into Turtle lake, the Little Mattawan river and Talon lake, which is utilized as far as Sand bay at its eastern end, a distance altogether of 21 miles. Trout and Talon lakes referred to above are very deep and fairly large bodies of water.

From Sand bay there is a canal for 3 miles to the Mattawa river, which is utilized as far as the town of Mattawa, a distance of 13 miles, where another canal cut ¾ mile in length makes an entrance into the Ottawa river.

This river, which expands into large and deep lakes in many places, is followed all the way down to the foot of Lake of Two Mountains, a distance of 293 miles.

From the foot of Lake of Two Mountains to Montreal, a distance of 25 miles, either the St. Lawrence river or a branch of the Ottawa river, called Rivière des Prairies, flowing north of the island of Montreal, may be utilized. The former route has 5 miles of artificial waterway, and the latter about 11 miles.

By the first route, the canal enters Montreal harbour at its upper end. By the second route, the St. Lawrence ship channel is joined at Bout de l'Ile, some 11 miles below the eastern boundary of Montreal harbour, or 17 miles below the city Customhouse.

For the whole route the aggregate length of purely artificial waterways is astonishingly small, being estimated at 28 miles.

Apart from that, with the scheme shown on plans, about 80 miles of lake and river beds are required to be improved by dredging or excavation, leaving 332 miles of natural waterways wider than 300 feet, and over 22 feet in depth, not requiring any improvement.

Character of the Ottawa River.

The Ottawa river has a basin of 56,043 square miles. From its source, which is almost directly north of the city of Ottawa, at the height of land which marks the commencement of the slope to Hudson Bay, to its junction with the St. Lawrence river, is a distance of about 750 miles. To the west and south of the basin

is the divide which separates the waters draining into the Great Lakes and the St. Lawrence.

On map No. 3 is shown the entire drainage basin of the Ottawa, with the respective areas of the sub-basins of each tributary. A detailed list of all the tributaries with their watershed area is also given in the report relating to the question of storage and control of flood waters.

Of the total area of the basin, about four-fifths is drained by the northern tributaries, and one-fifth by the tributaries lying south of the river.

The most important of the tributaries emptying into that portion of the river utilized for the waterway below Mattawa are on the north side: the Maganasibi, the DuMoine, the Black, the Coulonge, the Gatineau, the Lièvre, the Rouge and the Du Nord; to the south are the Petawawa, the Bonnechère, the Madawaska, the Mississippi, the Rideau and the Nation.

Above Mattawa are the Montreal and Kippewa rivers.

The river is generally a series of deep and wide basins connected by restricted parts, which are broken up by falls and heavy rapids.

Some of the many large lakes in the upper reaches, which drain into Lake Temiscaming, itself an enlargement of the Ottawa river, are the Expanse, Quinze and Grand Lake Victoria.

The northern part of the Ottawa valley is remarkable for the great number of its lakes, offering great possibilities for storage of water. It is rich in timber, and every year very large quantities of logs are floated down to the mills at different points. The population in the upper part is small, and agriculture has not yet been largely developed. Minerals seem to be abundant and distributed over a large area.

The discharge of the Ottawa varies largely, but there are no sudden variations, and the freshets come only once a year, always at about the same time. It may be said that, in general, the lowest stages occur in September, October, and often continue throughout the winter months, and the highest stages late in May and June, on account of the late spring at the head-waters.

The record high water is held by the rise in the year 1876, which reached almost 25 feet above the low water record of 1846—at the Rideau lock gauges at Ottawa. The corresponding fluctuations of flow and water level at other points vary according to the location and character of the river, and are given in a table accompanying the report in connection with storage.

Generally, excepting in 1876, the high waters of the south tributaries are past before the flood of the north tributaries begin, and the maximum of the two occur while the south are receding from their maximum and the north are approaching theirs.

The extreme high water discharge is stated to have been over 300,000 cubic feet per second at its outlet during the spring of 1876.

The extreme low water discharge may be as low as 20,000 cubic feet per second, showing a relation between the low and extreme flow of 1 to 15.

The low water fall from the head-waters of the Ottawa to Mattawa is about 600 feet and from Mattawa to the St. Lawrence at Montreal about 465 feet, occurring in rapids of various lengths and in sudden falls at many places.

The geological formations along the canal route from Mattawa down to Des Joachims are mostly granite and gneiss, but the river runs in some places through glacial drift deposits of apparently great depth. For the portion between Des Joachims and Chats falls the rocks are for the most part crystalline with considerable areas of crystalline limestone and occasional outliers of sedimentary rock in the near vicinity. Between the Chats and Montreal, the rock is mostly of a sedimentary character, composed of sandstone, limestone and shale.

It is stated by geologists, that it appears from the great depth found in this river at some points and from the occurrence of the sedimentary formations at so many

places in the bed of the stream that the old valley of the Ottawa represents a period of great erosion, since the channel was evidently excavated before the deposition of the sedimentary rocks from the Potsdam up.

Between Des Joachims rapids and the mouth of the Ottawa, several changes of level have taken place in past ages. This is indicated by the presence of terraces of sand and clay, and of old river channels which have since been filled up by drift deposits forcing the river to make new channels for the Ottawa waters.

It is believed that, at one time, a very much larger discharge flowed through the Ottawa valley, and the bed of the river is generally of larger proportionate area than many later rivers.

For this reason, the floods are generally kept well within its banks, and during the present period at any rate there is very little erosion, excepting in some alluvial parts of the river, for instance, below the Gatineau, where extensive low alluvial deposits exist, extending in a long belt of varying width between the present course of the river and the major well defined banks of the former stream.

The country below Ottawa for some miles along the north shore is rich in minerals. Important deposits of mica, apatite, graphite, &c., are found. Iron also occurs at several places and has been mined to some extent. Large quarries are worked with profit at many places.

Interesting and valuable information is given in regard to the geology along the proposed canal route, in a report by Mr. R. W. Ells of the Geological Department, supplemented by Elfric Drew Ingall, mining engineer of the Geological Survey, in regard to mineral deposits. These reports were obtained through the courtesy of Mr. A. P. Low, deputy minister of the Geological Survey, and are published in Appendix S.

The Ottawa river is navigated from Ottawa down to the St. Lawrence river, canals and locks having been built to overcome the Grenville, Carillon and St. Anne rapids.

The draft available through these canals is about seven feet at extreme low water.

In 1907 the total freight passed through the Ottawa river canals amounted to 337,850 tons. Of this 218,000 tons consisted of lumber in various forms.

Through navigation is interrupted by the Chaudière falls at Ottawa, but above several stretches are navigable. These are the Deschenes lake, the Chats lake, the Coulonge lake, the Lower Allumette lake, and the stretch between Pembroke and Des Joachims. The boats used are of shallow draft and engaged in towing logs only, with the exception of a few which carry passengers.

Barge navigation exists on a large scale below Ottawa. From 200 to 350 barges come up every year to carry lumber from points on the Ottawa river to Montreal, Quebec, Lake Champlain and other points. The capacity of these barges is about 300 tons. They carry from 30 to 50 millions feet of lumber annually, and they deliver from 6,000 to 10,000 tons of coal to points on the Ottawa per season.

Character of the Mattawa river.

The Mattawa river rises in that chain of lakes existing at the divide between the Ottawa and Lake Nipissing slopes, which are known as Talon, Turtle and Trout lakes. From the foot of Talon lake, where the water drops 43 feet in a narrow gorge through high granite cliffs, to the junction of the Mattawa with the Ottawa is a distance of about 15 miles; including the lakes forming the source of the river, the distance is 32 miles. With its tributaries it drains an area of 880 square miles, which has a very small population. The main tributary is the Amable du Fond which empties below Talon and Paresseux falls.

The extreme high water discharge is estimated at 4,000 cubic feet per second at the mouth, and the extreme low discharge 250 cubic feet per second, having a flood range of about 8 feet.

The total fall between Trout lake and the Ottawa is 180 feet, most of which occurs between Trout and Talon lakes, at the foot of Talon lake and at the Paresseux falls.

Below Talon chute, the river is generally restricted between rocky walls, the only remarkable expansion on its course being Plain Chant lake with a length of about 5½ miles.

The high stage of the river is generally during the month of May, and the low stage in August, September and October.

Along the Mattawa the rocks are chiefly granite and granite-gneiss. A small outcrop of crystalline limestone is seen near the foot of Talon lake, which has been used for lime-burning to some extent.

There is no navigation on the river, but the stream and its tributaries are extensively used by lumber interests for the floating of logs down to the Ottawa river.

A timber dam exists in the lower part of the river, which furnishes power for lighting the town of Mattawa. Only one bridge spans the river, at Mattawa.

At the head-waters of the main tributaries several lumbermen's dams exist which are used to store water for log-driving purposes.

Character of the French River.

The French river and tributaries have a basin of about 907 square miles, and the extreme high water discharge is estimated to be between 12,000 to 14,000 cubic feet per second at the mouth, and the extreme low discharge about 3,000 cubic feet per second.

The low water fall is 62 feet from Lake Nipissing to Georgian Bay where it empties, a distance of 63 miles. The flood range on the river varies from 8 to 10 feet.

The river flows entirely through a rock formation of the granite-gneiss variety, and on its course receives the waters of several tributaries, the most important being the Pickerel, Wolsey, Wahnapitae and Restoul. For the first 12 miles of its course, or from a point called Frank's bay to the Chaudière falls, the river may be taken as an arm of Lake Nipissing, and is often called the southwest arm of that lake.

In this part it has an average width of one-half mile, contracted at many points by numerous rocky islands, and a depth of 40 feet and over. Chaudiere island divides the river into two branches, called the North and Main branches.

The first break occurs there, where the river takes a plunge of 25 feet, the other main breaks below being the Five Mile rapids, the Recollect fall, and the Dalles rapids, near French Village harbour, on Georgian Bay. From its source on Lake Nipissing to Georgian Bay, where it empties by three main branches, called the Western, Middle and Eastern outlets, the river passes through a rocky and barren country, and its course is a succession of wide and deep expansions and narrows between high granite walls, with many sharp bends.

In one of these expansions, called Ox lake, about 13 miles up the river, the Pickerel river empties, after a course parallel to that of the French, from Cantin's island down, a distance of 7½ miles.

At Cantin's island, which really forms a barrier to the whole flow of the French from falling into the Pickerel, two small streams find their way westward.

The possibility of using the Pickerel for the proposed waterway for that part which is parallel to the French river has been considered, and the result is detailed in Mr. S. J. Chapleau's report.

Lake Nipissing, which forms the head of the French river, is a large body of uniformly shallow water, having an area of about 320 square miles and draining a basin of 4,077 square miles.

The shores in many places are very low, and it cannot be maintained much above high water level without flooding valuable property and a considerable area of low lands.

The rocks generally around the lake are granitic, with the exception of small outliers of Black River limestone, holding fossils, which are found on several of the Manitou group of islands. Small outcrops of crystalline limestone are also seen.

The extreme fluctuation of the lake is about 8 feet, and no difficulty is anticipated in regulating its level at any elevation near its high water stage.

At the outlet of the French river is French Village harbour. This harbour is formed by one of the several indentations peculiar to the rocky formation of the Georgian Bay coast line. It has an average width of 500 feet, with a depth of about 30 feet of water, excepting at some points where there are islands or pinnacles of rock which will require to be removed for large navigation.

The inner end of the harbour receives the discharge of the Middle branch of the French river, which has been selected as the most favourable for the proposed waterway.

Outside, the Bustard islands, about three miles distant from the mouth of the harbour, offer good protection against southerly winds, which have full sweep of the lake and bay.

The channel from outside the Bustard islands to the harbour, although passing near several reefs and rocky shoals, is well defined by range lights on the islands, and at the mouth of the harbour itself. It is recommended, however, that this part of the Georgian Bay be closely surveyed and swept by the Hydrographic corps of the Marine and Fisheries Department, as the approaches may require further improvements.

The Georgian Bay is remarkably free from fog, the average, from United States charts of 1901 and 1902 being not over 4 days in any month.

General Description of Project.

The question of the proposed new transportation route being a matter of national importance, it was determined from the inception of the survey, that the investigation should be so broad in its scope that no doubt could exist as to the practicability of the waterway for large navigation, the value of the final projected location, the distribution and design of the governing structures, and the estimated cost.

The data collected, therefore, was such as to permit of a canal project being developed that would allow the navigation of the largest lake steamers in the carrying trade. The tendency in regard to the lake freighter construction is to increase the length and beam, the draft being practically fixed and limited to 19 and 20 feet. This condition of a fixed limited draft is imposed by the limit of depth through the submerged artificial channels connecting the Great Lakes; the St. Mary's river, St. Clair river, Lake St. Clair and the Detroit river. The depth varies between 20 and 22 feet, and these conditions are likely to prevail.

Full information and discussion regarding these channels will be found in Appendix P.

The depth on the sills and in the reaches of the proposed waterway was fixed at a minimum of 22 feet.

In fixing the dimensions of the lock chambers, the size of the largest lake freighters now building was considered, with the result that the locks estimated for, are 650 feet in length, and 65 feet in width, thus allowing for a reasonable increase in the size of boats.

In regard to width of channels, this was determined to be at least 300 feet in submerged cuts, and a minimum of 200 feet in canal cuts.

The navigation scheme is connected intimately with a proposed storage system to control the flood waters of the Ottawa river, and to increase the low flow, this being considered advisable in the interests of navigation and industries depending on water-powers.

These questions are discussed fully, further in the report.

The project was therefore based on the above-mentioned governing features.

Starting from Montreal two routes are available: The front or Lake St. Louis route, and the Back River or Rivière des Prairies route.

By the first route, from Montreal to Georgian Bay, 23 ponds or levels are created varying in length from 1 to 60 miles, and connected by 27 locks of various lifts, to overcome the difference in level, flights of two locks being used at three different points.

By the Rivière des Prairies route, the distance from the lower end of Montreal harbour to Georgian Bay is about 20 miles longer, but the project as designed shows 22 ponds requiring 26 locks.

Further as it will be possible to create an extension of the harbour, back of the city of Montreal where splendid facilities for terminals exist, the distance in this case would be about the same as by the Lake St. Louis route.

Considering the Lake St. Louis line first:—

Montreal Reach.

The first pool formed above the level of that of the harbour of Montreal is effected by building a lock and cross wall at the lower end of Windmill Point basin, between Mackay embankment and Bickerdike pier. The Verdun dike is raised and strengthened and a small bay between Nun's island and the dike is closed by an embankment about four miles in length, extending up in prolongation of the Mackay pier from Victoria bridge to Nun's island and to opposite Verdun hospital, forming a pond generally over 22 feet in depth, where boats may go at full speed and where space will be available for docks, &c.

This pool will be controlled and kept permanently at about flood level, or at elevation +52 above mean sea level. Taking the low water level in the harbour at elevation +18, a step of 34 feet is thereby created.

A double track railway bascule bridge of improved type is provided, over the canal at the approach to the Victoria bridge, and the highway traffic will be served also by bascule bridges on each side of the railway bridge.

It is provided that the culvert beneath the Mackay pier will be enlarged and altered to form a regulation culvert for the basin.

The raised water level projected interferes to some extent with that part of the Montreal city waterworks which operate during summer time by water-power, and also with the Water and Power Company's works.

The drainage of Verdun and that brought down the old river St. Pierre is also affected.

These difficulties are fortunately overcome as explained in Mr. Coutlee's detailed report.

The total length of the pool level is 4·82 miles.

In relation to width, the channels with a depth of water of 22 feet and over may be classified as follows:—

Lock and approaches	0·87 miles.
Channels, 450 to 1,000 feet	3·65 "
Channels, 1,000 feet wide and over	0·30 "
Total	4·82 "

Approximate time to navigate, including 45 minutes delay at lock, 1½ hours.

Estimated cost, adding 10 per cent for engineering and contingencies, $4,244,827. See Plates 4 and 39.

Lake St. Louis Reach.

The Verdun lock, forming the foot of this reach, has a lift of about 18 feet, which, however, will vary with the level of Lake St. Louis, which is not controlled. Briefly,

this reach consists of a canal cut 3 miles long, then an embankment canal along the shore two miles up to Lachine, then 15 miles through the north part of Lake St. Louis to Ste. Anne de Bellevue.

Some intake pipes are disturbed by the proposed canal, but in every case provision is made for their extension farther out into the river and into deeper water, ensuring improved quality of water.

A sluiceway is provided at the Verdun lock to regulate the supply of water into the basin below.

As the reach is crossed by the Canadian Pacific railway below Lachine, a double-track bascule bridge is provided, giving a clear passage of 160 feet between abutments.

Lake St. Louis fluctuates between elevations 66 and 72, and very heavy rock excavation is required to give a depth of 22 feet below low water level.

Two quarter bends occur in this reach, one at mile 8 and one just below Ste. Anne de Bellevue, which, however, is in deep water with good width.

The Lachine canal navigation will not be interfered with.

The total length of the reach is 19·81 miles.

Length of channels 22 feet deep and over of various widths are as follows:—

	Miles.
Lock and approaches	0·95
Channels 200 feet wide	2·06
" 300 "	13·56
" 400 to 500 feet wide	1·82
" 800 feet and over	1·42
Total	19·81

Approximate time to navigate, including passage at lock, 3½ hours.

Estimated cost of reach, $13,808,239.

See Plates 4 and 39.

Oka Reach (Lake of Two Mountains).

The step to this reach is made at Ste. Anne de Bellevue, by a lock which will vary in lift from 5 to 9 feet. The reach extends to Pointe Fortune, mile 24 to mile 49, and it is intended to maintain it at ordinary high water level or at elevation 75. All the structures, however, are designed of sufficient height to allow of a 4-foot rise over this level, or to elevation 79. Five outlets have to be controlled: these are at Vaudreuil, Ste. Anne de Bellevue, Cap à l'Orme, the Lallemand and St. Eustache, where regulating sluices are provided to govern the outflow.

At Ste. Anne lock, double-track bascule bridges are provided for the crossing of the Grand Trunk and Canadian Pacific railways.

The total length of this pool level is 24·61 miles.

The channels, according to width, may be subdivided as follows:—

	Miles.
Lock and approaches	0·70
Channels 300 feet wide	5·40
" 500 feet wide and over—depth over 30 feet	0·91
" 1,000 feet and over—depth over 30 feet	17·60
Total	24·61

Approximate time to navigate, including 45 minutes for lockage, 3 hours.

Estimated cost of reach, $2,567,365.

See Plates 4, 5 and 40.

As Pointe Fortune lock is common to both routes mentioned at the beginning, a brief description of the Rivière des Prairies alternative project will be given here, before passing to the reaches above.

Rivière des Prairies Line.

St. Lawrence ship channel to Prairies lock.

The first lock on this line is located opposite Rivière des Prairies village, 5 miles up the river above Bout de l'Ile. The channel leading to it leaves the Montreal-Quebec St. Lawrence ship channel near Varennes, about 17 miles below the Montreal city Custom-house.

The channel is designed to allow of either up or down-bound traffic from the ship channel entering the Ottawa.

The water surface of the St. Lawrence at Bout de l'Ile is at elevation 16, which continues to the Prairies lock, where a lift of 24 feet is made. Considerable excavation is required in the approach to the lock. The line passes through Ile Bourdon, and at this point the Chateauguay and Northern railway is crossed, and a double-track bascule bridge has been estimated for.

The St. Eustache branch or Mille Ile river empties into this level.

Prairies Reach.

The surface of this reach is established and controlled at elevation 40.

A rock-fill dam is placed between the lock and the south shore, provided with stop-log sluiceways of sufficient capacity to pass the regulated flow with an excess of 25 per cent.

Heavy rock excavation is required at some points to enlarge the bed of the river, in order to pass the flow without excessive currents.

Some property will be damaged by flooding. This is covered in the estimate of cost. Cost, including approaches to Prairies lock, $6,267,580.

See Plates 4a and 38.

Recollet Reach.

The lock at Sault au Récollet provides for a lift of 35 feet, from elevation 40 to elevation 75, the regulated level of Lake of Two mountains, which is common to the front and Back river routes.

Above the lock—mile 17 to mile 28—is 11 miles of continuous canal cut, and where embankments are required, these have been designed 5 feet above the raised level of Lake of Two Mountains, to obviate any danger of overflow from the piling action of the water toward the lower end of the canal during heavy westerly winds.

Near the head of the canal a large area of sluiceways is provided, which will discharge overflow water directly into the river channel below, acting as safety valves against any rush of rising water in the canal cut.

Above the canal, the channel towards Oka village is through shallow sand flats which will have to be dredged for a distance of about 7 miles.

Bascule bridges are provided at Récollet lock, at the Canadian Pacific railway crossing mile 19, and at Cartierville.

A traffic roadway is also provided over the Bigras island sluices.

In connection with this route all other outlets of the Ottawa to the St. Lawrence are controlled by stop-log sluiceways.

From a common terminal at Pointe Fortune the time of transit by the Back river will be 8 hours to the ship channel, at the foot of Montreal island.

The whole cost of the reach is placed at $8,554,260.

See Plates 4a and 38.

Pointe Fortune Reach.

The Pointe Fortune works are designed for a raise of 40 feet, elevation 75 to elevation 115. This is obtained by one lock with the usual crib approaches, 2 miles of canal, and a large rock-filled dam near the head of the canal at Dewar island, provided with regulating sluices placed upon the rock surface of the island, sufficient to pass the whole flow of the Ottawa.

A considerable area of farm land will be destroyed, the cost of which is covered by the estimate.

For the upper 2 miles of the reach very heavy submarine rock excavation will be required.

A traffic highway bridge of the bascule type is located at the lock, which gives access to the land north of the canal.

Wherever required, in all reaches stone bank protection is provided for.

Total length of reach is 10·30 miles, made up of channels of various widths, as follows:—

	Miles.
Lock and approaches	0·75
Channels 200 feet wide	1·76
" 300 "	1·15
" 800 to 1,000 feet, 30 feet deep	5·12
" 1,000 feet and over, 30 feet deep	1·52
Total	10·30

Approximate time to navigate, including 45 minutes delay at lock, 1¾ hours.

Estimated cost, $4,246,905.

See Plates 5 and 40.

Ottawa Reach.

This reach is about 60 miles in length, and extends from Hawkesbury to Ottawa. The Hawkesbury lock has a lift of 25 feet, the raise being from elevation 115 to elevation 140.

Above the lock is a river flat which is converted into a small lake by an embankment along the river shore, extending 1½ miles up to the Hawkesbury mill pond. At the lower end a dam extends from the lock to the steep hill side.

This reach is maintained by a dam across the river located at the head of the Long Sault rapids, where solid rock foundation is secured. This dam is a succession of stop-log sluices.

The large saw-mill of the Hawkesbury Lumber Company at Hawkesbury will not be interfered with by the raised level.

Bascule bridges are provided for the saw-mill service and the Great Northern railway.

Considerable excavation, crib-work and embankment is required immediately above the lock, but from this point to Ottawa, very little work is necessary.

Although the proposed level of this reach is only the ordinary high water level, considerable land will be permanently flooded, which is now inundated every year from four to six weeks.

A sum has been placed in the estimate for the purchase of these low lands.

The channels 22 feet in depth and over, may be classified according to their width as follows:—

	Miles.
Lock and aproaches..	0·92
Channels 200 to 250 feet wide..	1·00
" 300 feet wide..	3·58
" 300 to 500 feet wide..	5·29
" 600 to 1,000 feet..	3·63
" 1,000 feet and over; depth, over 30 feet..	46·33
Total..	60·75

Approximate time to navigate, including passage at lock, 6¾ hours.
This reach is estimated to cost $6,786,849.
See Plates 5, 6, 7 and 41.

Hull Reach.

The project for the Hull reach is to pass back of the City of Hull, in the valley of Brewery creek, thus avoiding the Chaudière falls with its numerous power developments and established industries.

Two locks are designed, about one mile apart to overcome a difference in level of 55 feet which exists between Lake Deschênes and the foot of the Chaudière falls.

The first Hull lock makes a rise of 28 feet, elevation 140 to 168.

Above the lock is a basin, which is in rock cutting, with the exception of the upper portion crossing Brewery creek, where a bank 25 feet high on each side of the canal is required. A concrete culvert passes the water of Brewery creek under the canal.

The existing railway lines are diverted and rearranged for a total length of 6 miles, and a bascule bridge is located at lock No. 1 to pass the Canadian Pacific railway lines.

Estimated cost of reach, $2,556,153.

See Plates 7 and 42.

Aylmer Reach (Lake Deschenes).

This reach has a total length of nearly 34 miles, and the rise created by Hull lock No. 2 is 27 feet, elevation 168 to elevation 195. The lock is situated near the railway station. To the south of the lock is a regulating culvert, which will supply water to the reach below.

Above the lock is a canal nearly a mile long, which makes an entrance into the river just above the Prince of Wales railway bridge.

Close to the end of this canal is located the Chaudière dam, which is designed to be a huge rock-fill stretching across the river to Merrill island, and thence, following a chain of islands, to Mechanicsville. Sluices of the stop-log type of sufficient capacity are provided to pass the regulated flow of the river.

The raised level will obliterate the Deschênes rapids, the Remicks and the Little Chaudière, but the head-races of the Chaudière powers will be maintained at practically constant level throughout the season.

Heavy excavation is required at Deschênes rapids, at mile 149, and in the approach channel to the next lock above. At Deschênes rapids the channel is excavated 500 feet wide, to enlarge the sectional area of the river, in order to pass the June flow at a speed which will not interfere with navigation.

A bascule bridge is placed at Hull lock No. 2 to pass the highway traffic, and for the use of the electric railway.

The project necessitates the flooding of considerable land ; some powers are destroyed, and in some parts the public roads, the steam and electric railway tracks on both sides of the river are covered by the raised water. Provision is made for the

rebuilding of these tracks on higher ground, and the damages are included in the estimate. Extension of the Ottawa city waterworks intake beyond the proposed dam is also included in the project.

It may be necessary, if the canal is built, to place a small lock through the south end of the proposed dam, in order to pass rafts of logs, or barges, to the mills below. But conditions may be changed when the canal is built, and it is impossible to foresee at the present time what will be necessary to meet the requirements of this centre of industry.

The channels available are:

	Miles.
Locks, approaches and canal cuts between locks........	2·20
Channels 300 to 350 feet; depth, 22 feet.............	1·96
" 500 to 600 feet; depth, 22 feet.............	2·20
" 1,000 feet wide and over; depth, 25 feet and over.	27·50
Total............................	33·86

Approximate time to navigate, including 1½ hours' delay at locks, 4¾ hours.

Estimated cost of reach, $6,159,043.

See plates 7, 8 and 42.

Arnprior Reach (Chats Lake).

The dam governing this reach is located at the head of a canal cut about 1½ miles long, immediately above the lock situated on Egan island. This lock commands a rise of 50 feet, the highest lift proposed on the route, and raises the level of the canal from elevation 195 to elevation 245.

This lift was adopted after the most complete investigations made by the district engineer, and full discussion of all questions involved. The site selected was found to be most favourable, as the chamber will be cut out of solid rock, and lined with concrete, requiring only about 10 feet in height of wall to be built, above the surface of the rock.

As to the question of gates for such high lifts, very large steel gates are actually in use under very severe stresses, and the exhaustive investigation made by Mr. Henry Goldmark, C.E., showed clearly that for these large rises, steel gates are quite safe and of very simple operation.

Mr. Goldmark was consulted in this regard, and has designed steel gates for the project.

He was also commissioned by the Panama canal authoritites to design gates 74 feet high and for a width of lock much superior to the case under consideration, viz., 110 feet.

Under the conditions above mentioned, I fully concur with the district engineer in recommending the adoption of a 50-foot lift, instead of two locks in flight.

Above the lock heavy excavations and embankments are required.

The dam is of the rock-fill type, and sluices for regulation are placed on rock foundations, on two islands near the south shore.

No great damage from flooding occurs in this reach, as Chats lake is held at ordinary high water level. Considerable land, however, of little value will be rendered useless at Norway bay, as well as at Black bay and at the mouth of the Bonnechère river.

This level has a total length of 19·71 miles, and the channels available, 22 feet in depth and over are as follows:—

	Miles.
Lock and approaches	0·92
Channels 200 feet wide	0·83
" 300 "	1·50
" 600 "	0·91
" 1,000 " and over; depth, 25 feet and over	15·55
Total	19·71

Approximate time to navigate, including 45 minutes for lockage, 2¾ hours.
Estimated cost, $3,020,269.
See Plates 8, 9 and 43.

Portage du Fort Reach.

The works for this reach consist of a lock located in one of the Chenaux islands, with a lift of 35 feet, elevation 245 to elevation 280: a rock-fill dam across the steamboat channel to the south of the lock, and to the north extending across the islands to the head of Elliot island, and then across the north channel; of regulation works in prolongation of the dam, and located upon the flat rock top forming the north shore, and where an off-take channel is excavated.

The length of the reach is about 13 miles, and heavy rock excavation is required at many points.

At Portage du Fort there is a highway bridge; it is proposed to remove the middle span and replace it by a bridge of the bascule type.

Some land will be flooded at the lower end of Portage du Fort village and around the shore of Limerick island.

Several sharp bends in the alignment cannot be avoided.

The width of channels is very irregular:

	Miles.
Lock and approaches	0·80
Channels 300 feet wide	1·10
" 300 to 600 feet; depth, 22 to 30 feet and over	2·15
" 600 to 1,000 feet; depth, 22 to 30 feet and over	4·60
" 1,000 feet and over; depth, 22 to 30 feet and over	4·50
Total	13·15

Approximate time to navigate, including time for lockage, 2¼ hours.
Estimated cost, $2,235,516.
See Plates 9 and 43.

Rocher Fendu Reach.

This is a short reach, about three miles in length, 35 feet higher than the one just described. Rocher Fendu lock No. 1 is located on the north side of the river, at Flat rapids, on a ledge of rock. The dam governing the reach stretches from the lock diagonally across the river, and regulation sluices are placed upon a rock point which forms the south shore buttress of the rock-fill dam.

	Miles.
Lock and approaches	0·87
Channels 350 to 500 feet wide	1·63
" 1,000 feet wide	0·53
Total	3·03

Approximate time to navigate, 1¼ hours.
Estimated cost, $1,630,026.
See Plates 9 and 44.

Coulonge Lake Reach.

The raise to this reach is 35 feet, elevation 315 to elevation 350, which is about the flood level of Coulonge lake, and the distance between the locks is 19 miles.

The lock is designated under the name of Rocher Fendu No. 2 and is located at mile 190 in a projecting rock point of the north shore, where a suitable depression for a lock site exists.

The dam maintaining the proposed level is a rock-fill, which crosses the depression alongside the lock, and passing over the higher part of the point, crosses the north channel of the river to Lafontaine island.

The channel north of this island is closed by a similar rock-fill dam.

Considerable excavation in solid rock, sand, gravel and boulders is required to give the channels a sufficient depth.

The necessary regulation sluices are placed on a high flat rock across the gully from the lock, the rock surface being just about the proper height.

There are several bends in the alignment of the canal.

The raised water will cause very little damage.

Regulation works are necessary in the north channel at the Calumet falls below Bryson. This channel has been carefully examined, as a possible alternative route, and a project designed for comparative estimates. This route is described in the detailed report of the Montreal and Ottawa district engineer under the heading of Alternative Routes.

The total length of Coulonge Lake level is 19 miles. The channels according to width may be subdivided as follows:—

	Miles.
Lock and approach	0·70
Channels, 300 feet wide	8·54
" 400 to 1,000 feet wide	6·56
" 1,000 feet and over	3·20
Total	19·00

Approximate time to navigate, including lockage, 3 hours.
Estimated cost of reach, $4,334,461.
See Plates 9, 10 and 44.

Pembroke Reach.

This level extends from mile 209 to mile 265, a distance of 56 miles, past Pembroke, Petawawa and through Deep river to Des Joachims. It is formed by raising Lower Allumette lake to the level of the upper lake, or to elevation 370. The lift of the lock is 20 feet. It is located at Paquette rapids and the level is maintained by the ordinary rock-fill dam and the stop-log type of regulation works.

The dam extends across the foot of Fitzpatrick island, where the regulation works are situated and across Reid island.

On account of the doubtful quality of the limestone rock forming the foundation of the Paquette lock, alternative routes and sites have been investigated which are detailed in the district engineer's report.

At the Allumette rapids, conditions are such that the enlargement of the section of the river is necessary to pass the flow without currents injurious to navigation. This is obtained by widening the shipway from 300 to 600 feet.

To the north of Allumette island is the Culbute channel, in which a timber dam and lock was constructed in 1877. These works will be removed and replaced by regulation sluices to govern the Pembroke reach.

The Culbute channel has also been investigated as a possible route for the waterway, and an estimate based on a project which is detailed elsewhere.

In the event of construction, it will be advisable to further consider the advantages of the Culbute channel route as compared with the Pembroke channel.

No great damage is done by the raised level which is that of ordinary high water, above Pembroke.

Submarine and dry rock excavation is necessary at many points.

The channels 22 feet in depth and over, on this section may be classified as follows in relation to their various widths:—

	Miles.
Lock and approaches	1·00
Channels 300 feet wide	1·65
" 400 to 600 feet wide	5·00
" 600 to 1,000 feet	2·13
" 1,000 feet and over; depth over 30 feet	46·65
Total	56·43

Approximate time to navigate, including 45 minutes delay at lock, 6½ hours.

Estimated cost of reach, $4,840,099.

See Plates 10, 11 and 45.

Des Joachims Reach.

The lock and all structures at Des Joachims are designed for a lift of 40 feet, raising the level from elevation 370 to 410. The lock is located in a bluff rock point opposite the village, and is cut for about two-thirds of its depth in solid rock.

Over the lock is placed a bascule highway bridge to accommodate traffic at that point, and over the rock-fill dam across the river a roadway is provided for.

Regulation is obtained by stop-log sluices, for which solid rock foundation is secured.

There is considerable rock excavation at different points. Very little damage is done by the raised water level.

To avoid the Des Joachims rapids an old pass of the river north of the village, called the McConnell Lake pass, was investigated and quantities taken for a possible channel. No advantage being secured, it was abandoned.

The length of this level is 18·20 miles with the following available channels 22 feet deep and over.

	Miles.
Lock and approaches	0·63
Channels 300 feet wide	1·42
" 400 feet to 600 feet	2·35
" 600 feet to 1,000 feet; depth, 30 feet and over	9·56
" 1,000 feet and over; depth, 30 feet and over	4·24
Total	18·20

Approximate time to navigate, including passage at lock, 3 hours.

This reach is estimated to cost $2,998,141.

See Plates 12 and 45.

Rocher Capitaine Reach.

This reach extends from the Rocher Capitaine rapids to the Deux Rivières rapids a distance of 12·65 miles, and the difference in level of 60 feet between the lower and upper pools is overcome by a flight of two locks, each having a lift of 30 feet.

The locks are placed at the lower end of a cutting through the spur of the hills to the north of the rapids, and dams and regulating works at the head of the rapids maintain the river level at the proposed elevation of 470.

A cut 250 feet bottom width, 1¾ miles long joins the upper end of these locks with the river above.

Solid rock foundation is secured for the locks.

Two dams are designed to maintain the upper pool level, one across the main channel and one across the branch at the upper end of the Rocher Capitaine island. They are of the rock-fill type.

Regulating sluices of the 'Stoney' type running from the north end of the river dam are proposed to govern the flow. They will close openings 20 feet deep by 40 feet wide between concrete piers and are designed to pass 40 per cent in excess of the maximum regulated flood discharge. Running from the north end of the regulating sluices to the raised water contour is a concrete dam having an average height of 20 feet.

This reach is wide and deep, and no excavation is required in the river channels; several bends occur but they are of easy curvature.

No damages are caused through raising the water surface.

The width of channels in this level which are mostly over 30 feet in depth, are as follows:—

	Miles.
Two locks in flight and approaches	0·60
Channel cut 250 feet in width	1·60
Channels 500 feet to 600 feet	0·50
" 1,000 feet and over	9·95
Total	12.65

Approximate time to navigate, including 1¼ hours for passage at locks 2½ hours.

The works connected with this level will cost about $4,309,690.

See Plates 12 and 46.

Deux Rivières Reach.

The next step is made at the Deux Rivières rapids, where the river is raised 30 feet above the pool below,—elevation 470 to elevation 500. This will give navigation through to the town of Mattawa, a distance of 20 miles.

Two projects were investigated for the lock location and the controlling works. In the project selected the canal line enters the south shore below the Deux Rivières rapids, where the lock is located.

A rock-fill dam is thrown across the river in line with the lower end of the lock, and between the lock and the dam are the regulating sluices of the 'Stoney' type, the openings being 30 feet deep by 40 feet wide. The lower entrance crib on the north side of the lock will extend for some distance below to deflect the current from the sluices. The lock rests on rock foundation. Above the lock is a canal cut about 1½ miles long, and 250 feet wide with an embankment on the river side. A concrete core wall from the upper entrance of the lock on the south side extends to the limit of flooded area.

In this reach considerable land will be flooded, and the amount of damage has been provided for in the estimate. The raised water will necessitate a new location for the main line of the Canadian Pacific railway from Deux Rivières station to a point at or about Klock station, a distance of approximately 6½ miles. A relocation has been provided for.

This reach contains few bends, all of easy curvature. A small amount of channel excavation is necessary at different points.

	Miles.
Lock and approaches	0·63
Channel cut 250 feet in width	1·35
Channels 300 feet in width	2·75
" 350 feet to 600 feet	2·40
" 600 to 1,000 feet	6·80
" 1,000 feet and over	7·85
Total	21·78

Approximate time to navigate, including 45 minutes for lockage, 3 hours.
Estimated cost, $2,717,463.
See Plates 13 and 46.

Mattawa Reach.

At the town of Mattawa, the line of the waterway leaves the Ottawa to follow the valley of the Mattawa river, and pass through the Summit lakes forming its source.

The adopted line, after the consideration of several projects, for the Mattawa reach, leaves the Ottawa river at the foot of Johnson's rapids and passes along a natural depression behind the town of Mattawa into the Mattawa river one-half mile above its mouth.

The lock, which will have a lift of 10 feet, is located just inshore from the Ottawa river. Conditions were found to be such that a relatively low lift had to be considered at that location. At the lock site the material is cemented gravel and boulders, and the depth to rock could not be ascertained positively on account of the difficulties encountered in making the bore holes. Rock surface, however, was met with in the vicinity at no great depth.

The pool will be maintained by a solid concrete dam of the overflow type, thrown across the Mattawa river about 2,000 feet from its mouth.

A small quantity of mud will have to be excavated in the river to obtain grade.

Damage to property is confined to a few dwellings in Mattawa. The right of way within the town limits for the canal and lock will necessitate the purchase of considerable property, all of which has been included in the estimate.

To meet railway requirements, two bascule single-leaf bridges are provided for.

The length of this level is only 2·20 miles:

	Miles.
Lock and approaches	0·93
Channel 300 feet wide	0·87
" 600 to 1,000 feet wide	0·40
Total	2·20

Approximate time to navigate, including lockage, 1 hour.
Estimated cost of reach, $1,656,077.
See Plates 13 and 47.

Plain Chant Reach.

At the head of the Mattawa reach, 1¾ miles above the town, is Plain Chant chute, the outlet of an expansion of the Mattawa above, called Plain Chant lake.

The gorge forming the outlet is the selected site for the dam controlling the next reach, which is designed to stand 30 feet above the Mattawa pool, the water surface being raised from elevation 510 to elevation 540.

The lock is situated in the side hill of the north shore. The dam, which is of concrete and of the overflow type, spans the river from the upper end wall of the lock to

the south shore. A concrete cut-off dam joins the north upper wall of the lock with the raised water contour on that side.

Rock foundation is secured for the lock and cut-off dam.

For the foundation of the regulating dam across the river it is doubtful if solid rock can be reached, and the dam may have to be bedded in the boulder drift, which seems to be characteristic of all this district.

The power necessary to operate the lock, as at many other locations, will be derived from a hydro-electric plant, which in this case will operate and light both the Mattawa and Plain Chant locks.

The total excavation at different places is relatively small. This reach is 6·60 miles long, very wide at its lower end and narrowing considerably for the upper two miles. No valuable lands are flooded.

	Miles.
Lock and approaches	0·72
Channels 200 to 300 feet wide	1·10
" 350 to 600 feet	3·42
" over 1,000 feet	1·36
Total	6·60

Approximate time for navigating, 45 minutes delay at lock, 1½ hours.
Estimated cost, $1,598,951.
See Plates 13 and 47.

Les Epines Reach.

At the foot of this reach the works are designed to raise the water surface to elevation 557 or 17 feet above the Plain Chant level. This is accomplished by a concrete dam of the crest overflow type, between the La Rose and Les Epines rapids, with a lock and approaches cut through the side hill to the north. Both the lock and dam will be on rock and hard pan foundation.

Excavation will be required at a few points. The raised water will do no damage, excepting in the vicinity of Moore's lake, which lies between the river and the main line of the Canadian Pacific railway, where considerable land of very little value will be flooded.

This level is only 4·62 miles in length, and the widths available in channels are:—

	Miles.
Lock and approaches	0·56
Channels 250 to 300 feet wide	1·17
" 300 to 600 feet wide	2·35
" 600 feet and over	0·54
Total	4·62

Approximate time to navigate, including 45 minutes for lockage, 1¼ hours.
Estimated cost, $1,517,934.
See Plates 13, 14 and 48.

Lower Paresseux and Summit Reaches.

From the head of Les Epines reach, at the foot of the Paresseux falls, to Lake Talon is a distance of only 3 miles in direct line. Within this limit locks have to be placed in suitable locations to overcome a difference in level of 120 feet, between Les Epines and the Summit pools, Lake Talon being raised 40 feet to meet special requirements of the Summit as explained elsewhere.

Two alternatives were open for the project; to either follow the natural course of the river, or to practically cut a straight canal from the foot of the Paresseux falls through the divide to Talon lake, placing therein the necessary locks.

After mature consideration, and for reasons explained in the district engineer's report, the latter course was adopted as being more satisfactory for a canal of the intended magnitude.

The canal, therefore, as designed, about half a mile below the Paresseux falls, leaves the Mattawa river, and enters the side slope of the hills where a pair of locks in flight of 30 foot lift each will carry the canal up from elevation 557 to elevation 617. Above this point a natural basin exists which will form a convenient pool between the flight of locks just mentioned and another flight of two locks 1¼ miles above, having a similar combined lift of 60 feet.

This brings the canal to the adopted summit level, elevation 677.

The canal cuts to connect these levels are 250 feet in width, and in some places the excavation necessary will be at least 50 feet in depth.

Joining the end walls of the flights of locks, short concrete cut-off dams run to the flooded contour on either side.

To the east of the upper flight a series of small lakes which drain the surrounding hills flow into the natural basin about midway between the flights. This will be used to regulate the basin by means of sluice gates placed in a small dam, controlling these lakes.

The locks will all be operated by hydro-electric power.

To reach the Summit at both ends and for the Summit itself several routes were investigated and numerous propositions considered which are discussed in the report of the district engineer.

The Summit Level extends from mileage 334 to 357·5, a distance of 23·5 miles, embracing Lake Talon, the Little Mattawan river, Trout and Turtle lakes. All these lakes are raised to elevation 677 by means of a solid concrete dam thrown across the outlet of Talon lake about half a mile above Talon chute. This dam will have a length of crest of 1,100 feet and will rest on solid rock. Ten other dams varying in length from 150 to 650 feet, and from 7 to 17 feet in height are necessary to close gaps and depressions, where the raised water would run out to Lake Nipissing. These dams are designed to be built of earth with puddle cores.

Considerable excavation is required in Turtle lake and throughout the Little Mattawan river and at the lower end of Trout lake. Free navigation will exist for at least 15 miles of the reach.

To permit of the large summit basin thus created, acting at the same time as a reserve in seasons of deficient inflow, the lock sills at both ends are placed low enough to allow of the basin being lowered to elevation 671, without interference to navigation.

Supplementary sources of water are also made tributary to the Summit as is shown in reports relating to the water supply investigations.

At the upper end of Trout lake, the canal leaves the lake and passes through the divide which separates the summit waters from Lake Nipissing 3½ miles south-west.

The lock controlling the western end of the Summit reach, is located at the lower end of the rock outcrop which forms the divide and has a lift which will vary between 23 and 29 feet. The canal leading to the lock is 250 feet in width, and is in very deep cutting for part of the way. Its location, however, takes advantage of several small lakes and the valleys connecting them. At a point close to Trout lake, the heaviest cut of the whole project occurs. It runs 70 feet in depth for about one-eighth of a mile, and averages 40 feet in depth for five-eighths of a mile.

Very little damage will result from raising the summit water to elevation 677.

A single bascule roadway bridge is located across the lower approach walls of the lock.

The length of the Lower Paresseux level is 1·40 miles, and the width available in the canal cut varies from 250 to 300 feet.

The width of channels in the Summit reach may be classified as follows:—

	Miles.
Flight of locks and approaches	0·85
Channels 250 feet in width	3·35
" 300 feet in width	2·58
" 400 to 600 feet in width	2·58
" 600 to 800 feet in width	1·20
" 1,000 feet and over	14·20
Lock at west end and approaches	0·70
Total	25·46

Approximate time to navigate Lower Paresseux reach and Summit reach, 7 hours.

Estimated cost of Lower Paresseux reach, $2,775,449.

Estimated cost of the Summit reach, including the flight of two locks at the eastern end, and the lock at the west end, $9,210,813.

See Plates 14, 49 and 50.

NIPISSING REACH.

This is the first reach on the Lake Huron slope, the maximum drop from the Summit being 29 feet—from elevation 677 to elevation 648—at which elevation it is proposed to control the Lake Nipissing level.

This reach, which extends to the Chaudière falls on the French river, a distance of 30 miles affords practically free navigation for its entire length. The project is to raise Lake Nipissing about 8 feet above ordinary low water level and maintain it by building regulating sluices and dams across its outlets. The present level of the lake is governed by four natural outlets, or branches of the French river. The largest one occurs at the upper end of the Chaudière island, which divides the French river into two main branches. To the north of the island three small outlets drain the Nipissing level to the basin below, which is about 25 feet lower than Lake Nipissing. To the south of the island is the main outlet. It is proposed to span the three small outlets by solid concrete dams. The dam for the main outlet is also of concrete, but has three openings which will be closed by 'Stoney' sluice gates, the openings being 40 feet in width by 20 feet in depth. Rock foundation is secured for all the dams.

Leaving the western Summit or North Bay lock, a canal cut 300 feet wide and a little over 1¼ miles long, averaging about 22 feet in depth of excavation, brings the canal into 22 feet of water in Lake Nipissing. Most of this cut is in soft material. About 2,000 feet below the lock, a double-leaf bascule bridge is provided for the Canadian Pacific railway.

Long lines of crib-work are necessary in this approach, and the entrance from the lake is protected by pile work and earth embankment.

In the lake, the canal line passes south of the Manitou islands and enters French river, which is follewd for 12 miles to the Chaudière falls without any excavation being required.

The Chaudière lock is located some 1,400 feet from the falls along what is known as the Chaudière portage, and is designed for a drop of 24 feet, elevation 648 to 624. The site is of granite-gneiss formation.

Immediately above the lock, heavy rock excavation is required for the approach channel.

The raise of level in Lake Nipissing will cause damage by flooding at different towns situated on the lake shore, and to farm lands at the western end of the lake, the cost of which has been included in the estimates.

The town of North Bay, the most important place on the lake, will not be materially affected. Close to North Bay, about 2 miles of the Canadian Pacific railway track, in the vicinity of the Ojibwaysippi creek, will require to be raised about 4 feet. At Callender, some property and the railway yards of the lumber companies will be flooded. At all places where landing wharfs exist, they will have to be either raised or rebuilt in new locations.

The centre line of channel of the Nipissing reach does not present extreme changes of direction.

For operating the North Bay lock and bascule bridges, it is intended to provide a gas-producer electric plant. Hydro-electric power will be used for the Chaudière lock.

The channels 22 feet in depth and over may be subdivided as follows, in relation to width:—

	Miles.
Channels 300 feet to 600 feet	2·93
" 1,000 feet and over (Lake)	27·90
Lock and approaches	0.70
Total	31·53

Approximate time to navigate, including usual delay at lock, 3¾ hours.

Estimated cost of reach, $3,632,494.

See Plates 14, 15 and 50.

Five Mile Rapids Reach.

This reach is 13½ miles long and is proposed to be controlled by a lock and dam at the foot of the rapids, and by blocking a channel which exists to the north of the Eighteen-Mile island dividing the French into two branches.

The lock is located in a rocky point at mileage 403, and will effect a change of level of 24 feet, from elevation 624 to elevation 600.

To the north of the lock a rock-fill dam about 550 feet in length spans the gorge through which runs the Little Parisian, the last of the Five Mile rapids.

By enlarging a gully to the south of the lock and placing therein stop-log sluices, regulation of the reach is partly obtained.

The regulation will be completed by placing a similar set of sluices in the dam blocking the channel to the north of the Eighteen-Mile island. This dam will also be of the rock-fill type.

To obtain a channel of the desired width and alignment, many cuttings in rock are required where the rapids are now. Many bends occur in this reach, which cannot be avoided. There are no damages caused by the raising of the river.

The length of the reach is 13½ miles and the channels vary in width as follows:—

	Miles.
Channels 250 feet in width	3·45
" 400 to 600 feet and over	5·86
" 1,000 feet and over	3·64
Lock and approaches	0·50
Total	13.45

Approximate time to navigate, including delay at lock, 2¼ hours.

Estimated cost, $3,479, 138.

See Plates 16 and 51.

Pickerel River Reach.

This reach forms the last step from the Summit to Georgian Bay, the western end of the proposed waterway. It is 37 miles in length and stands at elevation 600 which is 21·5 feet above the lowest water recorded for Lake Huron.

The project is to follow the main channel of the French river, below the Five Mile rapids lock for a distance of 11 miles, thence the line is diverted through a natural waterway requiring considerable improvements, and enters the Pickerel river at the Horse-shoe falls, which it follows to its junction with the French river at Ox lake 16 miles below.

From Ox lake the line follows the middle outlet of the French into the Georgian Bay. This route was selected after careful investigation, as the least expensive and more adaptable to desired width of channels and alignment than the main body of the French.

Heavy rock excavation is necessary at many points.

The natural waterway leading to the Pickerel consists of two lakes connected by narrow channels.

Through the Horse-shoe cut will exist the sharpest bend of the whole canal location, and provision will have to be made to prevent vessels from crossing one another within this cutting.

To maintain this reach at elevation 600, four dams are required, blocking the different outlets of the French and Pickerel rivers into Georgian Bay.

One of these dams will be thrown across the head of the eastern outlet close to where it leaves the Pickerel river. Another will block the Bass channel one-half mile below, where the proposed canal line turns into the middle outlet. The third will be situated in the western outlet or Bad river about 6½ miles below Wahnipitæ lake. The fourth will control the middle branch on either side of the Dalles lock. These dams are designed to be of solid concrete of the crest overflow type, their combined crest length being sufficient for the regulation of this level without abnormal fluctuation. Rock foundation is secured for all these dams.

The lock is located on solid rock at mileage 440, about 100 feet from the shore, in the inner end of the coast indentation which forms French River harbour.

Below the lock for about 2 miles, leading to the main shore of the Georgian Bay, considerable submarine excavation is required at scattered points to obtain a channel width of 300 feet.

The entrance to French River harbour is comparatively narrow, and will have to be much improved, as well as the harbour itself. It is not presumed, however, that this harbour will be developed as a terminal.

The Pickerel reach is crossed by the Canadian Pacific and Canadian Northern railway lines, and bascule bridges of suitable lengths have been provided for in the estimate.

Damage by the raised level will be very small.

The width of channels for the Pickerel reach may be divided as follows:—

	Miles.
Channels 200 to 250 feet	5·60
" 300 to 500 feet	13·90
" 500 to 1,000 feet and over	16·75
Lock and approaches	0·60
Total	36·85

Approximate time of transit, including delay at lock, 5 hours.

Below the Dalles lock, through the harbour to the lake, the width of the channel varies from 300 to 500 feet.

Estimated cost of reach, including excavation in French River harbour approach, $7,162,786.

See Plates 16 and 51.

A full discussion of the project in all its details will be found in the report of Mr. C. R. Coutlee for that part of the route extending from Montreal to Des Joachims.

From Des Joachims to Georgian Bay full details will be found in Mr. S. J. Chapleau's report.

CHANNELS.

The total length of what may be termed canal cutting for the entire route is about 28 miles, by the project connecting with the St. Lawrence river above Montreal, through Lake St. Louis; and 34 miles, should the Rivière des Prairies route be selected.

The length of submerged channels to be excavated is about 66 miles, in stretches of varying lengths. Apart from this, there is an aggregate of 14½ miles of route where obstructions, such as shoals, sharp bends, &c., have only to be removed to form very wide channels.

Therefore, of the 440 miles constituting the waterway, 108 miles will require excavation work, for locks, approaches, canals, submerged channels, &c., leaving 332 miles of natural river or lake channels, which will not require any improvement beyond the raising of the water surface, as proposed by this project.

Taking into account the 14½ miles of obstructions, which after removal will leave wide, free channels, the route may be subdivided as follows, in relation to width:—

	Miles.
Canal cuts, 200 to 300 feet wide, including necessary restrictions at locks	28
Improved channels, submerged sides, 300 feet wide	66
Free channels, 300 to 1,000 feet wide and over	346
Total	440

The relative length of canals and submerged channels may be varied slightly, as it is an open question as to the exact point where the one ends and the other begins.

This scheme, as mentioned before, is essentially a river canalization, and short artificial canals are used as much as possible only for lock locations and approaches, which very often are placed in the natural streams.

Formerly, when canals of small dimensions only were required, there was a tendency to use artificial cuts for canals rather than use the natural streams, these being utilized only as a source of water supply; the reason being that the idea prevailed that swift currents, floods, &c., on rivers were difficulties which could not be successfully overcome for navigation purposes.

Conditions, however, are entirely changed, as it has been proven that natural waterways, with improved machinery and modern methods, can be regulated and made safe for navigation. The enormous increase in the size of boats require larger channels, and the universal practice now is to utilize the rivers and beds of streams rather than cut lateral canals.

Under this project, the sides of all submerged cuts will be shown by piers or clusters of piles at suitable distances, to indicate the channel and to aid vessels in navigating. Along curves these piers will be provided with lights, and each different course will be defined by ranges.

The restricted channels are widened at all bends, and conditions for navigation in these restricted parts will be as good, as on the St. Mary's river, or the St. Clair and Detroit river channels.

The depth of 22 feet selected for the waterway will more than equal the conditions as they exist to-day in the channels connecting the waters of the Great Lakes; the St. Mary's river, Hay lake, St. Clair Flats canal, and Detroit river.

The improvement carried out for these lake channels, since 1892, contemplated a depth of 20 feet below the mean water surfaces as determind up to that time. Since then, however, the prevailing water levels of Lakes Huron, St. Clair and Erie have been almost continuously below the mean stage as formerly determined, and, in consequence, the actual draft available, on account of lake fluctuations, has been only 17 to 19 feet. (Report of Chief of Engineers, U.S.A., Vol. V, 1907.)

It has, therefore, been found necessary to increase this depth, and some of these channels are now being deepened to 21 and 22 feet in order to obtain a safe 20-foot draft at all times.

The Georgian Bay Ship Waterway, with a minimum depth of 22 feet, will compare favourably with any of the channels above mentioned, which govern the draft of boats on the Great Lakes.

Information as to side slopes in different materials, hydraulic grades, &c., are given in the reports of the district engineers.

The total quantity of excavation required has been computed from actual cross-sections as determined by levels or lines of soundings.

The amount of rock and earth excavation in each reach, including quantities for alternative routes, are given in the section of the report which describes the project in detail, and in the tabulation relating to the estimate of cost.

The mileage of excavation in canals and channels for the route may be subdivided as follows, for each class of material encountered:—

	Miles.	Miles.
DRY EXCAVATION.		
Rock, about	25	
Earth, about	13	
Mixed earth and rock, about	20	
		58
WET EXCAVATION.		
Rock	18	
Earth	16	
Mixed earth and rock	16	
		50
Total		108

This mileage includes all points which are to be dredged or excavated, whether canal cuts, submerged channels or shoals. A small percentage given as submarine rock work might possibly be done in the dry, and the cost thereby reduced. In the estimates, when doubt existed, the rock excavation has been invariably classified as wet rock.

LOCKS.

The number of locks required for the project as designed is 27 for the route entering Montreal by way of Ste. Anne and Lake St. Louis. By the Rivière des Prairies route the number would be decreased by one. The lift of these locks varies from 5 to 50 feet and overcome a difference of elevation from Montreal to Summit level of 559 feet, and from Summit level to Georgian Bay of 98·5 feet, a total of 697·5 feet.

The number of reaches, however, is only 23, flights of two locks being provided for at the Rocher Capitaine rapids and at the Lower and Upper Paresseux falls.

After due consideration of all the conditions and requirements, a clear length of 650 feet and a clear width of 65 feet for the lock chambers, with a depth of 22 feet over the mitre sills, was adopted. These dimensions will accommodate vessels of the largest tonnage on the Great Lakes, and will provide reasonable accommodation for any probable increase in the size of boats.

Duplicate pairs of gates are provided at both ends of the locks, and should a longer chamber be required occasionally, a clear length of 707 feet would be available by leaving the inner pair of the lower gates open.

Lake boats have now attained a length of 605 feet, and though these are built especially for the iron ore trade, which goes to Lake Michigan and to Lake Erie ports, they may occasionally be chartered for grain and seek the Ottawa route, especially for late trips before the close of navigation. The locks and channels will pass them, but the waterway is better adapted to the common carriers, which has been so successful on the lakes, the 6,000 to 10,000 ton vessels, varying in length from 350 to 500 feet and over.

The depth over the sills is necessarily governed by the conditions at the Sault Ste. Marie locks and channels leading thereto, which practically limit the draft of the boats, when loaded, to 20 feet.

Therefore, it would seem that a depth of 21 feet over the sills and in the channels would have been sufficient to meet all requirements, but in order to allow an increased speed and a saving of time in some of the stretches of the canalized waterway, which is of vital importance, a ruling depth of 22 feet has been fixed.

A new lock at Sault Ste. Marie is contemplated by the United States government which will be 1,350 feet in length by 80 feet in width, so as to accommodate two modern lake freighters of the largest type.

The depth over the sills, it is stated, will be 24·5 feet, in order to increase the clearance under the vessels.

When this new lock is built, full advantage can then be taken of the new submerged cut through the West Neebish channel of the St. Mary's river below the locks. This channel, which connects the lower end of Hay lake with the upper end of Mud lake, has a total approximate length of 13½ miles, 2½ miles of which has been excavated through solid rock. This improvement was made at a cost of $4,500,000. The channel has a minimum depth of 22 feet below extreme low water in Lake Huron, and at that stage provides for the passage of boats of 20 to 21-foot draft.

The main purpose, however, of the new lock is to provide for the increase in traffic which is expected to pass through the Sault locks. The capacity of the Weitzel, Poe and Canadian locks is estimated at 75,000,000 tons per season, and with the traffic now approximating 60,000,000, it is evident, if the present rate of increase continues, in a few years the facilities afforded by a new lock will be urgently needed.

Now that the West Neebish channel is ready to be used, arrangements are being made, in order to better meet the development of tonnage and commerce, for the improvement of the Middle Neebish channel, which will be chiefly used for the upbound traffic.

It is proposed to give to this channel a clear depth of 21 feet below datum plane of 578·5 above mean sea level, through this portion of the river.

The following table of the depth of water available in the Poe lock for the last few years, in the Statistical Report of Lake Commerce, prepared under the direction of Colonel Chas. E. L. B. Davis, is of interest in view of the improvements to channels already made or projected.

DEPTH OF WATER IN POE LOCK—MONTHLY AVERAGES FROM DAILY READINGS.

Year.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1896	....	....	....	....	20·48	20·34	19·88	19·98	19·69
1897	19·36	19·82	20·22	20·63	20·80	20·60	20·31	19·99	19·97
1898	19·33	19·61	19·99	20·35	20·39	20·30	20·10	19·96	19·89
1899	20·01	19·94	20·47	20·84	20·98	20·01	20·70	20·44	20·37
1900	19·82	19·70	19·80	20·18	20·52	20·94	21·02	20·86	20·59
1901	20·11	19·96	20·20	20·39	20·60	20·17	20·08	19·72	19·42
1902	18·76	19·09	19·31	19·74	19·86	19·80	19·47	19·41	19·16
1903	18·95	19·33	19·55	19·84	19·97	20·08	20·01	19·71	20·31
1904	20·08	19·93	20·46	20·62	20·70	20·77	20·77	20·43	20·29
1905	19·89	20·04	20·29	20·70	20·75	20·78	20·72	20·43	20·14
1906	20·17	20·25	20·53	20·68	20·68	20·54	20·32	20·12	20·17

The above table shows that the average depth of water in the lock was less than 20 feet:—

Four months during the season of 1897.
Five " " " 1898.
One " " " 1899.
Three " " " 1900.
Three " " " 1901.
Nine " " " 1902.
Six " " " 1903.
One " " " 1904.
One " " " 1905.

In April, 1902 and 1903, the average depth decreased to 18·76 and 18·95 respectively, and in 1906 the average was only one-tenth to three-tenths of a foot above 20 feet for five months from April to December, inclusive.

This is of special interest in showing that with the proposed 22-foot depth at extreme low water in the locks and channels of the Georgian Bay Ship canal, conditions will be better than now exist on the St. Mary's river, and this depth will fairly meet the conditions created there by the new channels and prospective lock.

The passage through the Sault Ste. Marie locks gives a fair criterion of the different classes of boats engaged in the inter-lake commerce.

In the Statistical Report of the Lake Commerce passing through the Canadian and American canals at Sault Ste. Marie for the year 1906, the following list is given:—

VESSEL DIMENSIONS—FREIGHT CARRIERS.

Length.	Beam.	Number of Vessels.							
		Years.							
		1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
Feet.	Feet.								
30 — 100	8 — 28	53	44	16	39	20	6	26	13
100 — 200	21 — 39	283	316	275	243	219	183	194	170
200 — 300	32 — 43	267	285	303	337	314	291	293	258
300 — 400	38 — 50	124	134	152	179	174	181	183	171
400 — 500	45 — 53	41	56	71	87	97	118	128	128
500 — 600	52 — 60	....	....	....	....	....	1	23	57
Totals. ...	....	768	835	817	885	824	780	847	797

The foregoing table shows strikingly the sharp decline in the number of small freighters, and their outclassing by large vessels 400 to 600 feet in length.

In percentage to the whole fleet the different classes for the same year stand as follows:—

Years.	Class.				
	100 to 200.	200 to 300.	300 to 400.	400 to 500.	500 to 600
	p. c.	p. c.	p. c.	p. c.	p. c.
1899	39·59	37·35	17·33	5·73	0·00
1900	39·95	36·03	16·94	7·08	0·00
1901	34·33	37·83	18·97	8·87	0·00
1902	28·72	39·83	21·17	10·28	0·00
1903	27·24	39·05	21·64	12·07	0·00
1904	23·64	37·59	23·39	15·25	0·13
1905	23·63	35·69	22·29	15·59	2·80
1906	21·69	32·91	21·80	16·33	7·27

In 1906 the percentage of total freight carried by vessels of different classes was as follows:—

For vessels up to 1,000 tons, net register; length varying from 64 to 258 feet; maximum beam, 42 feet; total freight carried, 6 per cent.

For vessels 1,000 to 2,000 tons, net register; length varying from 172 to 366 feet; maximum beam, 45 feet; total freight carried, 19·3 per cent.

For vessels 2,000 to 3,000 tons, net register; length varying from 282 to 448 feet; maximum beam, 54 feet; total freight carried, 14·3 per cent.

For vessels 3,000 to 4,000 tons, net register; length varying from 368 to 484 feet; maximum beam, 53 feet; total freight carried, 34·1 per cent.

For vessels 4,000 to 5,000 tons, net register; length varying from 431 feet to 569 feet; maximum beam, 56 feet; total freight carried, 14·5 per cent.

For vessels 5,000 to 6,000 tons, net register; length varying from 474 to 602 feet; maximum beam, 60 feet; total freight carried, 11·6 per cent.

This shows that over 80 per cent of the freight which passed at the Sault locks, in 1906, was carried by vessels of a larger size than can be passed through the present St. Lawrence canal locks, and indicate clearly that the size of the lock chambers on the proposed route should not be less than 650 feet in length by 65 feet in width.

In designing the different reaches, great care has been taken to make them as few as the physical conditions would permit in order to make the route as fast as possible, and this has necessitated the adoption of lifts higher in many cases, than have so far been used in practice. The highest single life on the route is 50 feet, several others being over 30 and 35 feet, as is shown on the table referring to locks, page 316.

These unusually high lifts were selected only after the most exhaustive study of existing high lifts, and the consideration of conclusions reached by boards of prominent engineers in investigations made for other large canal projects.

A small lock built in connection with the Assouan dam, Egypt, has a lift of 60 feet. At Lockport, the end of the Chicago Drainage canal, a small lock is in use having a lift which varies from 30 to 45 feet according to the condition of the water level in the river below, and it is projected to build a large lock of the same lift in connection with the proposed waterway from Lockport to St. Louis, U.S.A. Several studies in France, Germany and elsewhere have been made, and locks with lifts of 40 to 60 feet, and even 65 feet, have been proposed by prominent engineers.

In France the lock with the highest lift is that at the head of St. Denis canal in Paris—32·2 feet with a maximum of 36 feet—built on rock in 1890-91.

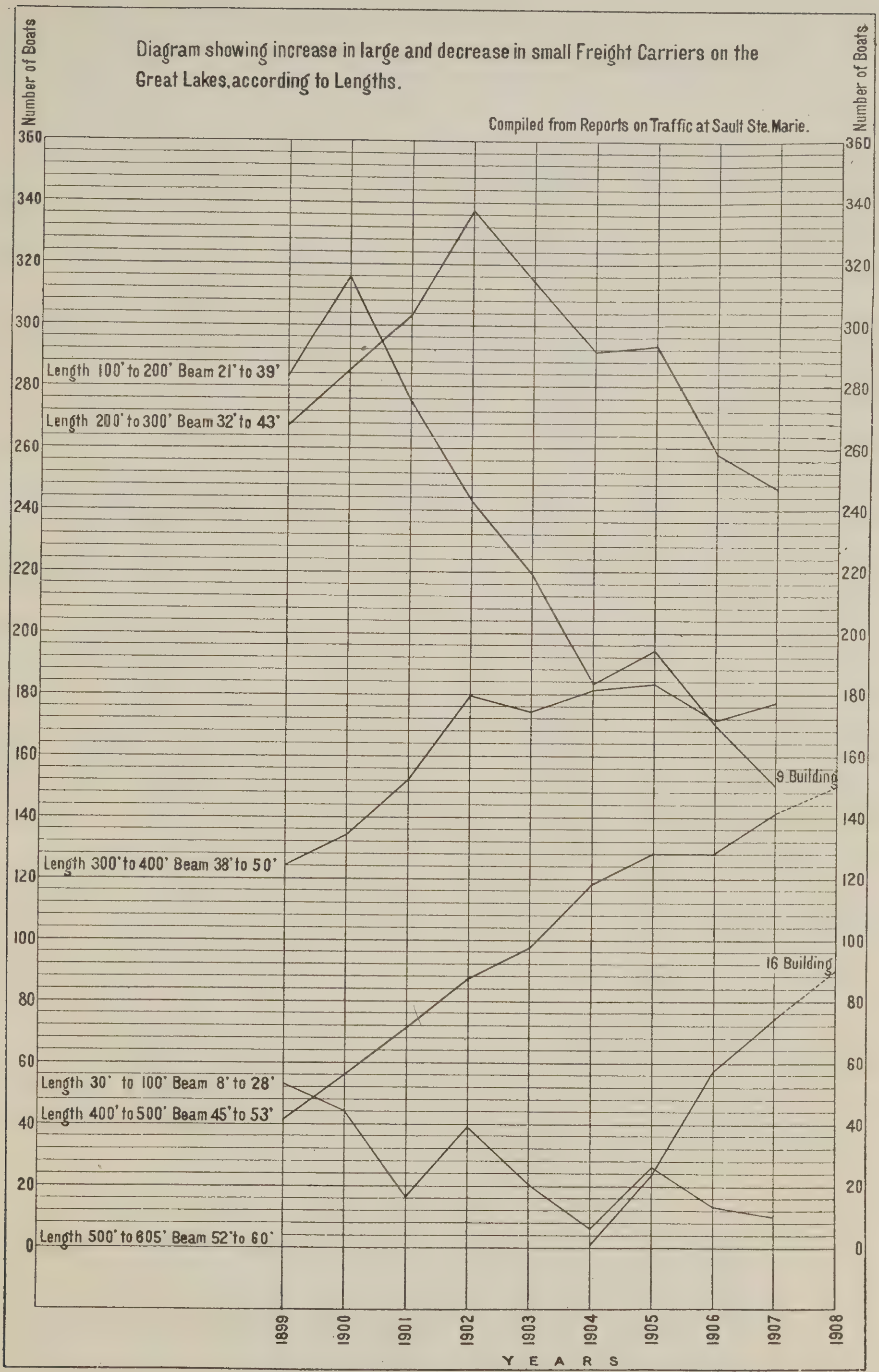


Diagram showing increase in large and decrease in small Freight Carriers on the Great Lakes, according to Lengths.
Compiled from Reports on Traffic at Sault Ste. Marie.
Number of Boats
Length 100' to 200' Beam 21' to 39'
Length 200' to 300' Beam 32' to 43'
Length 300' to 400' Beam 38' to 50'
Length 30' to 100' Beam 8' to 28'
Length 400' to 500' Beam 45' to 53'
Length 500' to 605' Beam 52' to 60'
9 Building
16 Building
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
YEARS

Another lock with a lift of 30 feet exists at Horin, on the Moldau in Bohemia, which was built on gravel foundation in 1902 and 1903. It is stated that both of these have been operated without any difficulty having been experienced from their great lifts.

Lock gates employed for coast work, have to close locks which are frequently as wide as 100 feet and in some of which the depth of water at high tide exceeds 50 feet.

Lieuteant-Colonel C. W. Raymond, Corps of Engineers, U.S.A., in a paper for the International Congress of Navigation held at Dusseldorf in 1902, states: 'It is practicable and in some cases desirable, to adopt lifts as high as 52 feet and gates can be constructed to safely sustain the pressure from the resulting heads. With low lifts the maximum freight capacity is greater, but high lifts facilitate the rapid passage of the individual ship.'

The Deep Waterway Commission in 1901 employed Mr. Henry Goldmark, C.E., to design steel gates for locks up to 40, 48 and 52-foot lifts. His investigations and designs showed clearly that steel gates of very simple construction and operation could be built for these high differences of elevation.

Mr. Goldmark designed gates for the Panama canal which are 74 feet high and for a width of lock of 110 feet; being much larger than those required on our proposed waterway.

This question was discussed with Mr. Goldmark and he has designed steel gates, which are shown on plates No. 32 and 33. His report in this connection with estimate of cost is given in Appendix C.

One of the reasons which led to the recommendation of such high lifts, apart from considerations mentioned above, is that the locks can be built under the best conditions possible of safety and stability.

Numerous borings and repeated investigations have demonstrated that all the locks, with one exception, will rest upon rock of such character that it will furnish a safe and stable foundation.

Such advances have been made during the last few years in concrete construction that all parts of the structure can be made permanent and of ample strength. Granite will, in most cases be at hand if it should be found advisable to build the hollow quoins and line the sluiceways for the valves, &c., operating under large heads, with that material. Without doubt, everything can be made absolutely safe in so far as the structures are concerned.

As to the passage of shipping, there is no difficulty to apprehend. Practical experience with large locks, large ships and an immense traffic on the St. Mary's river is conclusive as to safety of passage.

Substantial piers of approach and double gates are provided, and by using stationary power for the moving of vessels, danger to locks and to shipping in transit is reduced to a minimum.

A description of each lock, the arrangements of filling and emptying culverts, lighting and other details are given in the reports prepared by Messrs. Coutlee and Chapleau, and which are incorporated further in this report. The standard single lock and locks in flight as shown on plates 18 and 19 were designed by Mr. Chapleau for the Nipissing district. The standard single lock shown on plate 19A was designed by Mr. Coutlee as a type for the Montreal and Ottawa districts.

DAMS.

The total number of dams, large and small, required to be built in connection with the project is 45, not including those connected with the formation of storage reservoirs at the head-waters of the Ottawa river, which question is treated elsewhere in this report. Great care was exercised in the selection of the various locations for the dams, as there were many considerations, which require judicious adjustment. After having ascertained the character of the foundations by test borings, such matters as avoiding the flooding of large areas of valuable land, the adoption of lifts

which would allow a minimum number of dams and locks, the securing of deep water so as to reduce as much as possible submarine excavation in the upper end of the reaches, &c., entered into the final choice of the various locations.

On account of the different conditions existing at many of the sites, it was impossible to adopt a standard type for all the dams.

In the summit reaches the main consideration governing the character of the structures to be adopted was that no waste of water could be permitted. Therefore, in such cases, where the conservation of water is involved, water-tight concrete dams are provided for.

On the Ottawa river, the amount of water available, even at extreme low flow, is so much in excess of the requirements that a large amount of leakage through the structures is of no consequence.

Therefore, the dams provided for the main river are generally very large and of considerable height, and a type had to be found that would be absolutely safe, relatively easy of construction in strong currents or boiling rapids, and of reasonable cost. Timber dams in most cases could not apply, on account of their size being very much limited and the frequent repairs required. Large concrete dams are becoming very usual, but on a river like the Ottawa, for high dams and in deep locations, the cost would practically be prohibitive.

This question was particularly investigated by Mr. Coutlee, who recommends in his report, as most suitable, the type known as 'rock-fill dam.' After mature consideration of all the conditions and elements affecting this important part of the work, I have reached the same conclusion, and believe that the rock-fill dam for such a large canalization as proposed is the proper solution. Generally, where these dams are located, there will be such a large amount of rock excavated from the canal prism or lock sites, that it will be possible to dump this rock so as to gradually build these large rock-fills, even to a larger section than required by safety, at a reasonable cost. If it is desired to limit the leakage of these dams to a minimum, small material could be deposited in front to a flat slope. A great advantage with this type of dam is its absolute safety under all conditions. As expressed by Mr. Coutlee, 'This huge rock bank becomes really a part of the geology of the locality. It cannot be overturned like a masonry wall, nor can it slide upon its base. If the river bottom scours out beneath it to any extent, the loose stone settles into the cavity, and if by accident water pours over the top of it, the loose rock will no be eaten away to any extent, and under no circumstances will the dam burst suddenly.'

Many reservoir dams have been built of loose stone in California. One even has been built 210 feet high, thus exceeding in height the greatest masonry dams ever built. On the Ottawa no such extreme height is proposed, the highest above ordinary low water level being 25 feet, and from bottom in the deepest part of the river to crest level the highest construction is 80 feet.

With these dams an important element is that a speed of construction can be attained which cannot be equalled with any other material. Moreover, the tightness of a loose-stone dam can be progressively increased, according to the needs, by simply increasing the thickness of earth or protective material.

Of course, it is not intended to allow these dams to be over-topped, and movable dams or sluiceways are provided of sufficient capacity to pass the flow and at the same time to control the level of the different reaches.

A great number of types of movable dams were investigated, with the result that it was decided not to go beyond common practice on the Ottawa river, where ordinary stop-log dams have been in use, with great success, for many years. They cost less than any of the standard types in use, and they can be made certain of operation by improved handling machinery. In some special cases, however, it has been found advantageous to use large 'Stoney' sluice-gates, and an estimate of cost for various openings and depths, prepared by Mr. Henry Goldmark, C.E., is given in Appendix G.

In regard to these regulating dams, in practically all cases, solid rock foundations have fortunately been secured.

Sections and some detailed drawings are shown on the plans. Further detailed observations regarding the dams at each location, character of structure and dimensions are given in the reports of the district engineers.

BRIDGES.

Between Montreal and Georgian Bay there are now 13 bridges along the line of the proposed waterway.

The Lake St. Louis route and the Rivière des Prairies alternative route have the same number of bridges, four in each case.

Several of these structures, the Grand Trunk railway bridge at Montreal, the Hawkesbury bridge, the two railway bridges at Ottawa, and the Mattawa bridge are not directly affected, the canal line cutting their approaches where bascule bridges are provided.

A special study was made of each particular bridge, and sketches prepared for new structures over the canal, the bascule type, either single or double leaf, and single or double track, according to requirements, being selected in every case.

The following tables show the character and general dimensions of the existing bridges along the route, and the location and character of the proposed bridges under the project. See plate 34 regarding sections of proposed structures.

Name or Location.	Length.	Elevation of Floor above M.S.L.	Height above low water.	Description of Bridge.
	Feet.	Feet.	Feet.	
1 St. Lawrence River, Montreal.	6,450 (Approaches not included.	65·00	39	Grand Trunk Railway double track steel through bridge. 24 spans of 250 ft. each; 1 channel span of 330 ft.; Montreal approach, 1,100 ft.; St. Lambert approach, 700 feet.
2 St. Lawrence River, Lachine.	3,524½ (Between abutments.)	87·00	22	Canadian Pacific Railway single track bridge. 2 cantilever channel spans of 408 ft. each; 2 deck flanking spans of 270 ft. each; 8 deck spans of 240 ft. each; 3 deck plate girder (shore) spans of 80 ft. each. 60 feet clear under channel spans above ordinary water level.
3 Bout de l'Ile, Bourdon Island (Rivière des Prairies alternative route).	1,412	....	29	Châteauguay & Northern Railway single track steel bridge, over the south channel of Rivières des Prairies, comprises the following spans: 2 deck plate girder spans resting upon the abutments, each 46 feet in length; 8 through trusses, each 140 ft. in length, 21½ ft. deep, and a channel truss 200 ft. in length.
4 Viau bridge, Ahuntsic (Rivière des Prairies alternative route).	990	62·00	20	Highway steel bridge over Riviere des Prairies composed of 1 span of 208 ft., 1 span of 61 and 2 spans of 59 ft. each.
5 Bordeaux (Rivière des Prairies alternative route.)	514	73·00	20	Canadian Pacific Railway single track steel through bridge over Riviere des Prairies, composed of 1 span, 201 ft. in length; 1 span, 158 ft., and 1 span, 155 feet.
6 Cartierville (Rivière des Prairies alternative route).	665	71·00	15 6	Three steel spans highway bridge over Riviere des Prairies, having 1 span of 220½ ft., 1 span of 222 ft. and 1 span of 222½ ft.

No.	Name or Location.	Length.	Elevation of Floor above M.S.L.	Height above low water.	Description of Bridge.
		Feet.	Feet.	Feet.	
7	Ste. Anne de Bellevue.......	1,357¾	110·46	41	Grand Trunk Railway double track steel bridge over the Ottawa river, composed of 8 deck spans of 66 ft., 6 deck spans of 100 ft. (approx.) and 1 through truss of 206¾ ft.
8	Ste. Anne de Bellevue.......	1,342	111·21	41½	Canadian Pacific Railway double track steel bridge over the Ottawa river, composed of 7 deck spans of 66 ft. 1½ ins.; 1 deck span of 63 ft. 1½ ins.; 2 deck spans of 100¾ ft.; 1 through truss of 324 ft., 2 through spans of 104¾ ft., and 1 through span of 100¾ ft.
9	Hawkesbury..............	1,484	174·00	50	Great Northern Railway steel deck bridge over the Ottawa river, composed of 7 spans each 212 ft. in length.
10	The Royal Alexandra (not interfered with).	1,860	192·30	52	Single track railway steel cantilever bridge over the Ottawa river, between Hull and Ottawa. Double electric line, double roadway and double sidewalk on this bridge.
11	The Prince of Wales (not interfered with).	3,300	190·78	28	Canadian Pacific Railway single track steel through bridge over the Ottawa river, above Chaudière falls. The length given embraces Lemieux island and a smaller island.
12	Mackie Bridge.............. (Portage-du-Port.)	391	270·10	27	Interprovincial steel highway through bridge over the Ottawa river, main channel, between Limerick island and the Ontario shore, at the Narrows, composed of 1 mid-stream channel span, 305 ft. in length; 1 span of 53 ft. and 1 span of 33 ft., with stone piers and abutments.
14	Portage du Fort...........	200	268·16	27	Steel highway bridge over the Ottawa river between Limerick island and the north shore, at Portage du Fort Village. In 1872, the Department of Public Works, aided by the province of Ontario and the municipality, built a wooden bridge, which was destroyed in 1898. In 1900 a new structure consisting of 1 through span with stone piers and abutments and a steel superstructure was put up by the Department of Public Works—the Governments of Quebec and Ontario contributing.
15	Bryson..................	378	383	40	Steel highway bridge on concrete piers and abutments over the Ottawa river, Grand Calumet channel, between Grand Calumet island and Bryson village. Begun in 1886 and completed in 1888. Consisted of an approach on the Bryson side, formed of a timber Howe truss 66 ft. long, and timber trestle with stone embankment, 71 ft. long; an approach on the island side 47 ft. long with stringers laid on bents and stone embankment; two mid-stream steel spans 169 and 209 ft. long respectively and 17·2 feet wide. In 1906, the Department of Public Works rebuilt the bridge by inserting two new spans 65 and 100 ft. long respectively, and concrete abutments &c., at a cost of $15,500.
16	Chapeau	150	351	5	Wooden highway swing bridge over the Culbute Channel, connecting the village of Chapeau, on Allumette island, with the main shore.

No.	Name or Location.	Length.	Elevation of Floor above M.S.L.	Height above low water.	Description of Bridge.
		Feet.	Feet.	Feet.	
17	Des Joachims Rapids........	435	388·60	13	Steel highway bridge over the main channel. Built in 1882 by the Federal Government, contributions being made by the provinces of Ontario and Quebec. Cost, $47,309.88. Rebuilt in 1900, the provinces again contributing towards the reconstruction. NOTE.—Bridge across timber slide over the inside channel, between Laure island and the Quebec shore, consists of 2 steel through spans, each 150 feet in length, a stone centre pier and the abutments. This bridge will not be affected by the construction of the Canal.
18	Mattawa (not interfered with)	340	512·50	17	Steel highway through truss bridge over the Mattawa river, at Mattawa, concrete piers.
19	Pickerel River..............	249	....	....	Canadian Pacific Railway through steel truss bridge over the Pickerel River, at the 420·7 Mile Point, concrete piers.
20	Pickerel River..............	300	638·00 (approx.)	54	Canadian Northern Railway bridge over the Pickerel river, at the 430 Mile Point. One through truss span, concrete piers.

BASCULE-BRIDGES to be erected over the route of the Georgian Bay Ship Canal.

Number of Bridge.	Name of Location.	Width.	Description of Bridge.
		Feet.	
1	Victoria	55	Double track; double roadway.
2	Verdun	20	Highway bridge.
3	Lachine	25	Double track. Can. P. Ry.
A	Bout de l'Ile. (Alternative Route)	25	Double track.
B	Sault au Recollet. (Alternative Route)	20	Highway.
C	Bordeaux. (Alternative Route)	25	Double track. Can. P. Ry
D	Cartierville. (Alternate Route)	20	Highway.
4	Ste. Anne de Bellevue	25	Double track. G. T. Ry.
5	Ste. Anne de Bellevue	25	Double track. Can. P. Ry-
6	Pointe Fortune	20	Highway.
7	Hawkesbury	25	High level; double track. Great Northern Ry.
8	Hawkesbury	20	Low level; single track.
9	Hull Lock 1	20	Highway.
10	Hull Lock 1	25	Double track. Can. Pac. Ry.
11	Hull Lock 2	25	Hull Electric Line; 2 tracks and 2 roadways.
12	Portage du Fort	20	Highway.
E	Bryson. (Alternative Route)	20	Highway.
F	Fort Coulonge. (Alternative Route)	20	Highway.
C	Westmeath. (Alternative Route)	20	Highway.
H	Chapeau. (Alternative Route)	20	Highway.
13	Des Joachims	20	Highway.
14	Mattawa	20	Single track. Can. Pac. Ry. (Kippewa Br.)
15	North Bay	25	Double track. Can. P. Ry.
16	Pickerel	25	Double track. Can. Pac. Ry.
17	Pickerel	25	Double track. Can. Northern Ry.

REPORT BY MR. C. R. COUTLEE, M. CAN. & AM. SOC. C.E.—DETAILED DESCRIPTION OF ROUTE AND PROJECT.

MONTREAL TO DES JOACHIMS.

In October, 1904, I was appointed a member of the engineering board, to look into the question of the navigation of the Ottawa river from Montreal to the Great Lakes. The survey had already commenced under the Department of Public Works, and I was chiefly concerned in the general study of the requirements of the navigation proposed, and the design and cost of a scheme to meet these requirements.

The ship navigation project along the valley of the Ottawa consists in providing arrangements to bring boats of large size (600 x 60 x 20 ft. draft) from Lake Huron. Michigan (Georgian Bay), down through pond after pond to Montreal, the head of ocean navigation.

This style of river navigation is known as 'the lock and dam system,' with slack water reaches between, and is quite similar to the Rideau and Cataraqui river system between Ottawa and Kingston.

In designing these reaches, it was necessary to know the style of navigation proposed. A depth of 22 feet was set by the department, which indicates a vessel of 20-foot draft, corresponding to the large lake boat. I will, therefore describe this craft: her speed, load, habits, &c., and also the channels, curves and currents which the lake boat is accustomed to navigate.

The commerce of the great lakes consists of four commodities: iron ore, from Superior to Lake Erie; coal as return cargo from Lake Erie to Superior; grain—wheat, oats, flaxseed, &c., and lumber. The first two commodities form 80 per cent of the total trade. For the transport of iron ore and coal the monster lake boats have been developed.

These boats are limited to 20-foot draft, as even the greatest lake harbours are not deeper; but the length of the boat has been extended from 300 feet to 400 feet, then to 500 feet, and at present boats slightly over 600 feet are in the business.

The largest weigh, empty, 5,000 tons, and can carry a load of 12,500 tons. The engine is placed in the stern, not in the centre as with ocean-going craft. The bow is reserved for the bridge, wheel-house and officers' quarters, and the whole mid-ships portion—nearly 500 feet long—is one immense bin, 500 feet long, 60 feet wide and 25 feet deep.

The bottom of this bin is about 5 feet above the bottom of the ship, and the space between is divided into some twenty compartments, all or any of which may be pumped full of water for ballast.

The deck is a succession of hatches, with only the deck-beam of the main frame intervening. (See Plate 20, prepared by Mr. Chapleau.) As the boat lies at a wharf, with her hatches open ready to load, nearly all the deck has been removed, and she is a great box with the cover off, into which the iron ore is poured from elevated bins. In this way the steamer *A. B. Wolvin,* in July, 1904, loaded 11,000 tons of ore, and was under way in the short space of three hours. (*Eng. News,* 1904.)

Despatch in loading and unloading is essential to make these boats pay during the six months of navigation.

To unload, the boat is brought down under a series of mechanical unloaders, each of which consists essentially of a grab-bucket that descends into the iron ore, shuts its jaws, and rises filled with several tons, which it carries quickly to the pile along the back of the wharf, and returns for another mouthful. The load is discharged in some

seven hours at the dock. The coal and ore trade of the lakes is a highly specialized traffic, five times greater than the Suez canal tonnage, and loaded, carried and discharged more quickly than any freight elsewhere in the world.

The speed of these lake boats is moderate: 12½ miles in open lake has been found the economic rate, while an ocean freighter would be 50 per cent faster, but no delays are allowed at terminals.

The boat travelling 12½ miles per hour in open lake reduces her speed 10 per cent when passing water from 40 feet to 25 feet depth automatically, *i.e.*, without having the steam supply of her engines lessened. A further reduction to 9 miles per hour is considered advisable as she enters a channel dredged out 22 feet deep and 300 feet wide. The edge of this channel cannot be seen, of course, beneath the water, and there is danger that boats might touch along the sides with disastrous results, as the steel plates of which the hulls are constructed are remarkably easily torn.

If a large boat (600 feet) sinks in a dredged channel, she is very apt to swing crossways and obstruct all traffic for days until she is raised or a temporary channel dredged around her.

The following is an extract from *Engineering News*, 1900, Vol. I., page 264:—

'During the last season, 1899, there were three accidents in the history of transportation on the lakes illustratiing one of the serious and inevitable defects of such a highway of commerce.

'In its natural condition, the St. Mary's river, which connects Lakes Huron and Superior, had extensive shallow reaches. Through these a channel has been excavated 300 to 400 feet wide and 20 feet deep. In the early part of September, 1899, one of the Great Lake freighters, the *Douglas Houghton,* ore-laden, through the giving out of some of its steering gear, went aground; and swinging around across the channel, completely blocked it. It took five days of the most arduous and unremitting effort to get this vessel afloat and out of the channel; and, in the meantime, 332 vessels loaded with freight were unable to get by. To those interested this caused a dead loss, estimated by the Lake Carriers' Association at nearly $1,000,000.

'In the latter part of November, another blockade of the St. Mary's river channel occurred, due to a collision in which three vessels, two steamers and a tow barge, were mixed up and stranded. This caused a delay of nearly four days to some 167 vessels, and involved a loss to the navigation interests of a very large sum, probably not far from $500,000.

'In the early part of December, a tow barge went aground in the St. Clair Flats canal, blocking the canal for nearly two days, delaying 35 vessels, and causing a heavy loss to the navigation interests. This latter accident, occurring just at the close of the season of navigation, might have produced most serious results by preventing a great many vessels from reaching their destination and home ports.'

Long boats, especially when deeply laden, so that they, as it is said. 'smell the bottom,' are very liable to 'take a sheer' and run aground or collide with an approaching boat; consequently, a 22-foot channel is provided for a 20-foot draft boat.

In a canal her engines are shut down to half speed, as her great length requires cautious running to prevent sheering toward the sides. Even a less speed is necessary when meeting other boats, but 4 miles per hour is the headway required for steering.

In entering the Soo lock the speed is reduced to about 2 miles per hour just before coming to a dead stop in the lock chamber. (See Plate 36.)

Lake boats have a steering-gear which is very quick-acting, when compared with that of ocean boats. This admits of quick, sure and safe manœuvring. The ocean boat would be unable to make lockages and pass the bends and currents of the crowded

channels of the St. Mary's, St. Clair and Detroit rivers, through which the lake boats wend their way day and night with practically no accidents. (See Plate 35.)

On the other hand, the lake boat could not weather the storms of the North Atlantic, nor would her speed be economical in that service. The lake boat is a large, capacious, moderately-engined barge, built especially to carry iron ore and coal, and, during slack periods, grain in bulk.

The Ottawa navigation would necessarily conform to the requirements of these boats, and I have designed the channels, locks and piers with this end in view. (See Plate 37.)

Canal cutings are 200 feet wide at bottom, with 22 feet depth of water, and flat side slopes rising 1 vertically to 2 horizontally.

Submerged channels, i.e., channels dredged through shoals in the bottom of the river, are all 300 feet or more in width both in rock and earth. They have range lights to indicate their centre, and permanent cribwork marking piers along their sides instead of floating buoys. On each curve the permanent piers are placed at intervals along its edges and provided with lights.

The size of all narrow portions is made amply large to prevent currents exceeding 4 feet per second, or 2¾ miles per hour.

Curves or bends in the channel are all of one mile radius, but in twenty cases about one-half mile radius has been absolutely necessary. An inspection of plate 35 will show this to be the average radius of the path of boats passing the quickest bend on the lakes.

The St. Mary river, 50 miles long from the Soo down to Detour on Lake Huron, has been navigated for years at its worst point, the Neebish bend, with extremely few accidents, by thousands of lake boats meeting one another both day and night in clear weather, fogs and snow storms. (See Plate 35.) The Ottawa channel is in all respects equal to this stretch, or to the St. Clair and Detroit river channels between Lake Huron and Lake Erie.

These well known lake channels were thoroughly examined, and their proportions of width and depth investigated by the United States Deep Waterways Commission in 1901. They reported that a 22 feet depth and a width of 300 feet was sufficient, but that a constant effort should be made to straighten and widen the bends, and to increase the width to 600 feet whenever the cost could be undertaken.

LOCKS.

When it is necessary to raise a boat from a lower level to an upper level, a lock must be resorted to.

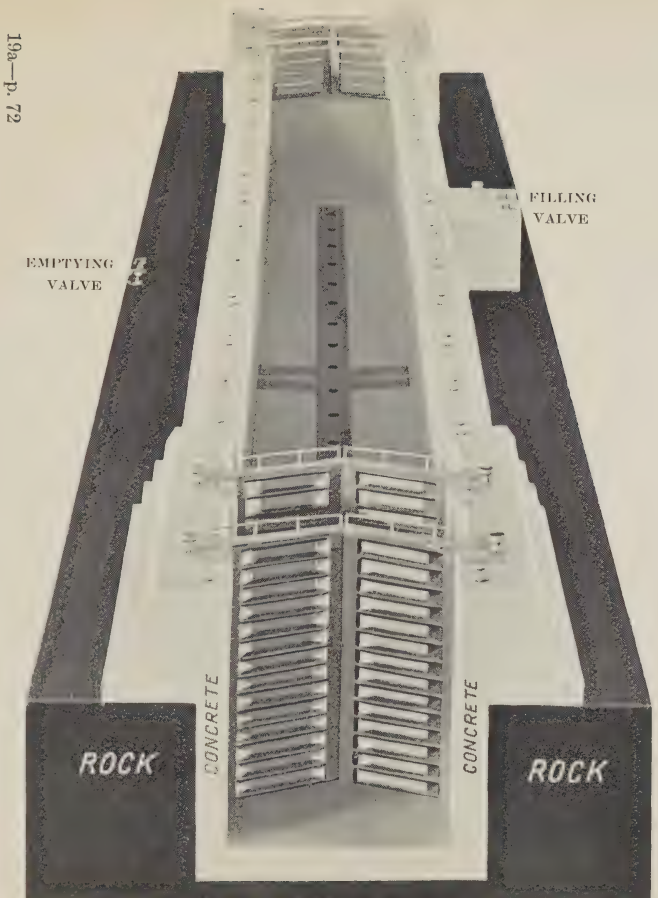
A lock is a large concrete box or basin with steel doors called 'lock gates' at each end. The bottom of the lock is level with the canal bed below, so a boat drawing 20 feet can sail in when the lower gates are open. (See Plate 19A and cuts of model of lock.)

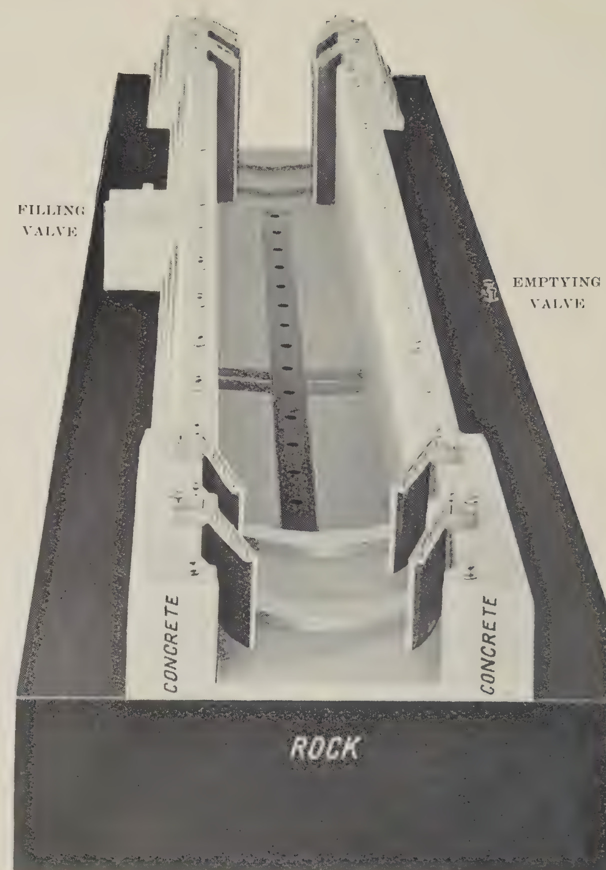
The upper end gates of the box are closed, and dam back the upper level. Now close the lower end gates and admit water from above, by a system of valves then, as the surface gradually rises, the boat floats up with it till the upper level is gained. Now open the upper gates and the boat can proceed to the next lock.

In descending, the boat enters the full lock, the upper gates are closed, the water is let out through sluiceways, and the boat slowly sinks with the water surface in the lock chamber.

This dock, or lock, or two-level basin, was invented by Leonardi da Vinci in 1500, and endures to the present day.

Mechanical lifts of many kinds have been built with great ingenuity, and, with caution, scows of perhaps 500 tons weight may be lifted by them; but the ponderous laker,—the cargo and boat weighing 16,000 tons, and worth half a million dollars, could not, in the present state of science, be risked in any elevating machine. Moreover, elevators need only be resorted to when the water supply is exceedingly limited.





MODEL OF LOCK

Looking into chamber from lower end showing double steel gates closed, side filling, floor culvert and incorporation of rock into side walls.

Looking into chamber from upper end showing gates partly opened, mitre sills and concrete walls on top of rock.

Length of Locks.—As to size of lock, Diagram, page 61, indicates that lake boats have attained a length of over 600 feet. Of course, the longest boats are to be considered as special craft employed in the iron ore trade only, but occasionally one of the 'big fellows,' as they are called, is chartered for grain, and may, consequently, seek the Ottawa route. Their load is so immense (425,000 bushels) and carried with such great economy, that, although only one or two may pass per year, they cannot be neglected, and so the length and breadth of lock have been made sufficient for their accommodation.

The locks at Sault Ste. Mary are the types to be considered in fixing the length and width. From Plate 37 it will be seen that the locks built or projected there are the largest in the world.

The Poe lock, 600 feet x 100 feet wide and 21 feet depth on sill (1896), was intended to accommodate four vessels, two abreast, but the freighters have outgrown the size, 400 feet x 45 feet. At any rate, the berthing of vessels side by side is a time-losing operation, and the proposed American lock, 1,400 feet x 80 feet wide, will after the example of the Canadian lock (900 feet x 60 wide) admit vessels one behind the other, tandem fashion.

While the Ottawa route locks may well be 650 long to admit the long freighter of the near future on 20-foot draft, it does not seem to me advisable to build them long enough for two such boats, nor even for two 350 to 400 ft. boats. Nothing at present points to a sufficient trade to overtax single locks within the next thirty years. Enlargement then would be best directed to placing another lock alongside the existing one, so up-bound boats would use one, and down-bound the other.

The new Welland and St. Lawrence locks, 255 x 45 (1870 to 1899), were found to be 100 feet too short for existing boats before completion. The Weitzel lock, 515 x 80 wide (1881), was exceeded about 1900, since when vessels 600 feet long, carrying 9,000 to 14,000 tons of pay freight, have come into the trade. There is no indication, however, that while the draft of 20 feet (West Neebish, 1907) obtains, the length will be increased beyond 625 feet.

An inspection of Plate 19A, or 20, will show the double gates at each end of the lock, the outer ones being a safe-guard. By using only the outside gates at the lower end a boat over 650 feet long may be passed occasionally. (See cuts of model of lock.)

Width of Locks.—A too great length of lock means greater cost to no useful purpose, and a longer time to fill and empty. Excessive width, however, is a more formidable matter, because each gate leaf becomes wider and must be heavier. Each leaf also transmits greater stresses to the lock walls. (See Appendix E page 457.)

Width very much greater than the beam of the vessel that enters is not desirable, because of the diagonal blows given by the boat. These, of course, injure the lock walls, but greater injury is sustained by the steel plates of the boat itself. On the other hand, a too narrow lock requires that vessels force themselves in under full propulsion power. When leaving, the water is forced out momentarily, and the keel may drag over the sill.

A margin of 2 feet on each side between the vessel and the lock wall seems ample. Boats are not made wider than 60, owing to the reach of unloading machines at lake harbours, but they are built up to this limit, and a few cannot enter the Canadian Soo lock, 900 feet x 60 feet wide.

A width of 65 feet (see Plate 20) is sufficient for the big freighters, and will allow a tug to remain alongside its barge when towing it 'under the wing.'

Depth on Miter Sills of Locks.—Ample allowance beneath a vessel's keel is always desirable. A boat is said 'to squat' or settle down when in motion. If drawing loaded 19 feet at the dock, the draft will be 20 feet when the propellor is moving. If a vertical steel plate, 60 feet long and 20 feet deep, were forced broadside on through the water at 18 feet per second (12½ miles an hour), the commotion caused by a ship

would be imitated. There would be a piling up of water in front, an escape at each side, and a flow into the depression behind.

Between a vessel and the channel bottom there is a tendency to compress the water, making the boat tremble as though it were moving on rollers. This tends to sweep loose stone and débris into heaps upon which the flat steel bottoms of heavy carriers may scratch and grind.

A minimum depth of 22 feet has been allowed over the top of the miter sill against which the lock gates close. The lock floor is still lower.

Lock Pits.—It has been the aim to secure solid rock foundations for all locks. Happily, this has been obtained, avoiding complications and engineering difficulties, which are always productive of waste and dissatisfaction. It has been said that 'nothing is permanent, except in so far as it accords with natural conditions.'

Wherever possible, it is proposed to cut out the lock chamber in sold rock, using the natural rock, evened up, of course, with concrete, as the sides of the chamber. This method was first proposed by the writer in 1899 for the French river navigation. It was made possible by the introduction of channelling machines, which cut a slot in the rock along the edge of the proposed excavation before blasting is begun. When the rock is blasted and taken out, the sides of the excavation are smooth and vertical, instead of rough and rugged. Channelling machines have been extensively used on the Chicago Drainage canal, where miles of the side are smooth and vertical. (See cuts.)

Lock chamber walls.—When the rock surface is too low, the lock wall is built up of massive concrete founded upon the rock. This method of construction is now employed in hydraulic power development for power-house walls, wheel-pits, &c.

Concrete alone, deposited in mass, is proposed for the lock walls including their coping, for the hollow quoin barrels in which the lock gates turn, and for the lock floor, its filling conduit and the miter sills. My experience convinces me that cut stone is less durable and more expensive than concrete, so quite unnecessary.

Large boats have been bumping for years against concrete walls without stone copings, and northern winters have made persistent attacks with only such minor injury as could be repaired conveniently, cheaply and well.

The hollow quoins and miter sills are the ledges against which the heel and bottom of the lock gates press while supporting their load of water. Concrete supports concentrated loads of buildings, of bridges and of dams without crushing or chipping; why then should it not support similar loads applied by steel lock gates?

For dimensions of lock walls, see Appendix E.

Entrance Piers at Locks.—The first requisite of a lock is safety, the next simplicity, and the next speed of operation. The time required to lift a boat is not so much dependent on the rapid filling of the lock with water as upon the time lost in cautiously entering and berthing the boat itself.

The boiled down experience of the Great Lakes' practice at the Soo is that a long pier should be provided above and below each lock. The face of pier should be the direct prolongation of the side of the lock, so that a boat can slip along the pier in a straight line to the lock chamber.

Heretofore it has been the custom to provide walls, splaying inwards like a funnel, to the lock, and these walls have been built of concrete. It has been found, however, that boats glance diagonally from these walls, inflicting blows upon the lock wall and constantly dinging in their steel plate sides.

I have, therefore, adopted straight lead piers of crib-work below water surface, with concrete walls on top. This type is very lasting, and preferred by lakemen to walls of concrete from the bottom up, because boats receive less injury during the season. The Canadian and United States governments have adopted this type at the Soo and other places. It is worthy of remark that, on the American side, wooden

Pit Excavation.

Steps would be evened up with concrete.

Channelling Machine at Work.

Chicago Main Drainage Canal. Channelled sides of excavation.

cribwork alone has stood thirty years of very heavy service. (See lock sites, Plates 38 to 45, and cross section of pier, Plate 19A.)

These walls extend 2,000 feet above and 2,000 feet below the lock where possible; a length sufficient for a couple of boats 600 feet long to tie up along and await their turn for locking. The pier is only provided on one side of the channel, the other side being left completely open, so that a long boat leaving the lock has a sufficient width of channel to get out of the way of an in-coming one.

The greatest danger to a lock exists when a down-bound boat refuses to stop through defective machinery, and crashes into the lower gates, which are already supporting a great height of water, and receive, in addition, the impact of the boat. The entrance piers are provided with snubbing posts, to which the moving boat may attach lines, that, even if they break and do not stop her, will check her speed.

Lock Gates.—The movable dams at each end of a lock are the gates. They are pivoted on each side of the lock and shut like a great pair of double doors, the two leaves coming together like an arrow head, pointing up-stream. They act like roof rafters against the thrust of the water's mobile weight, and transmit it to the side walls. (See cuts of model of lock.)

In Canada, lock gates have heretofore been made of wood, but steel gates are to be used throughout in this project, Mr. Goldmark, who designed the lock gates for the United States deep waterways, 1901, has designed the steel gates for this project. (See Appendix C and Plates 32 and 33), and Mr. Matheson has prepared the table of weights. See Appendix F.

Their construction is simple, each leaf consisting of two vertical posts; the pivot post being called the 'heel post,' and the other one the 'toe' or 'miter post.' Every 3 feet from the bottom upwards horizontal steel girders, 4 feet wide, ½ inch thick and about 35 feet long, stretch from 'heel post' to 'toe post,' forming a gridiron frame, to which steel sheeting is riveted. See Plates 32 and 33.

Each leaf revolves on a spherical pivot casting set on the lock floor. The bottom of the gate heel post is provided with a shoe casting, hollowed out to fit accurately on the pivot. At the top of the heel post is a steel pin, that revolves in the eye of a projecting arm anchored back into the lock wall. The gate is supported on these two attachments only and hangs free, there being no rollers under the 'toe.'

With a view to water-tightness, the heel post is of oak, and the contracts between the bottom of the gate and miter sill and between the miter faces are also of oak. See Plates 32 and 33.

The gate-heel is semi-circular, 20 inches diameter, formed of two oak posts, each a quarter circle fitted into each angle of a T-shaped steel column. See Plates 32 and 33.)

The post only fits the hollow quoin (hollowed-out corner) when closed and bearing the water pressure; a slight eccentricity in the pivots allowing the gate to swing open without friction against the quoin.

The miter of each gate is faced with an oak plank that, like the sill contact, may be renewed. It is important that the miter faces should be as wide as possible to prevent the gates accidently closing past each other.

The following from *Engineering News,* 1906, vol. I., page 238, is an extract from the minority report, Panama Canal, and clearly states the dangers at locks and the latest engineering practice in meeting them:—

'*Safety of locks and other structures.*—An accident to gates, if it occurs is most likely to result from a mistake in the engine-room, the engineer sending the vessel ahead when the pilot signals to back, and then the pilot, noticing that the ship's speed is not being reduced, and not realizing that the previous signal is not being carried out, signals for full power, or perhaps signals so rapidly that he cannot be understood. One or the other of these successions of events has

usually taken place when a ship has run into lock-gates. The carrying away of a lock-gate occurs but rarely, but it has occurred three times in the Manchester canal. It has never occurred in the St. Marys Falls canal.'

'In the Manchester canal the gates at the lower end of the lock were struck, the upper gates being open, the ship moving downstream, but in all cases the operating force was able to get the gates at the head of the lock closed, or so nearly closed that they came together and held back the water in the canal. If the accidents at the Manchester canal show that gates may be struck and destroyed, they also show that disaster may be averted even without special safeguards. Of all the possible movements of a ship at canal locks the one that involves the most danger of opening a summit level is when a ship bound down in that level approaches a lock, but by proper safeguards this can be made very small. If a gate is struck by a ship upward bound the water pressure on the opposite side of the gate helps to resist the blow. By the use of two pairs of gates at each end of the summit lock, all danger of opening the summit level by a blow on the downstream side of the lower gates is eliminated, as will be shown a little further on.'

'The canal construction should provide long approach walls at each end of every lock or flight of locks so that lines cans be put out quickly and handled readily and the ship held under perfect control. For this important purpose a long solid pier with suitable snubbing posts is vastly superior to mooring piles and floats, such as are used in some foreign canals.'

'With suitable approach piers and with rules duly enforced requiring ships to put out lines on arriving at the pier and to reduce speed to two miles per hour when moving along it, or to stop altogether several hundred feet from the lock, a great degree of security can be obtained. Such approach piers are provided in the lock plan herein recommended.'

'This plan also provides two pairs of gates at the head and two at the foot of each summit lock, so that a ship will always find two pairs of gates shut against it.'

'If the summit level is terminated by a single lock and the lower gates are struck by a ship upward bound, the gates at the upper end of the lock being open, the lower pair of gates at the foot of the lock having water pressure back of them will absorb the blow, and even if they are wrecked the second pair of gates, some 80 feet distant, will not be reached. The resistance offered by the first gates will almost surely stop the ship, and the rush of the mass of water, 80 feet in length between the two gates, will insure stoppage before it can reach the second pair. If the lower end of the lock is open and the upward-bound ship strikes the first pair of gates at the upper end of the lock, its motion will be stopped by these gates, the mitre wall and the water, and the second pair of gates will be left intact. We believe, therefore, that by the use of duplicate or safety gates at each end of the summit lock, all danger of opening the summit level by an upward-bound ship will be eliminated.' (See cuts page 71.)

'If a downward-bound ship is approaching the gates from the summit level it will find at least two pairs of gates closed against it, of which the first will be sustaining no water pressure to weaken the strength available to stop the ship. While this case does not afford the absolute security shown in the case of ships moving upstream, the possibility that the the ship will so completely wreck the first pair of gates as to continue its course to the second and seriously harm them, is extremely small. A large lock-gate is a massive structure, not easily wrecked. The gates of the Poe lock have been struck three times and injured more or less, but they continued to support the summit level.'

'The provision of duplicate gates at each end of a lock, herein adopted, is an unusual precaution. It has been recently adopted in part at the St. Mary's

Falls canal, where duplicate gates are now operated regularly at the lower end of the Poe lock, but the upper end is not similarly protected. In the additional lock now projected at that canal safety gates are to be provided at each end. The approach piers, the extent of which greatly affect the safety of a lock, are excellent at the St. Mary's Falls canal, and far better than at any other ship canal, and doubtless have contributed to the remarkable record of immunity from serious accidents.'

'This canal has now been in operation a little more than fifty years, and a traffic aggregating about 360,000,000 tons net register has passed through it, with no accidents seriously obstructing navigation. It is the best example existing not only of the capacity of a lock canal for a great traffic, but of the safety with which this traffic can be handled with suitable equipment.'

'But it must be remembered that it is easily possible to block a sea-level canal by the sinking of a vessel in its channel, either by design or by accident, such an accident, for instance, as that which caused the steamship *Chatham* to absolutely block the Suez canal and suspend all traffic through it for a period of nine days, from September 27 to October 6, 1905.'

'This accident occurred in time of peace in a sea-level canal, 36 years after its completion. During the period of 50 years since it was built there has been no such protracted interruption of traffic in the lock canal connecting Lake Superior with the lower lakes, and the delays in the channels away from the locks have constituted the most serious interruption to traffic on that waterway.'

'With duplicate locks, as proposed for the Panama canal, navigation would seldom be delayed at the locks, as it would be extremely improbable that both of them would be out of use at the same time. In an appendix information is also given respecting delays to navigation in the excavated channels of the St. Mary's and St. Clair rivers. These channels are much wider than the sea-level canal would be, yet they have been blocked on several occasins. In one instance, when the blockade continued for five days, 332 vessels were delayed, and the loss to navigation amounted to a large sum, estimated to be $600,000. The loss in such a case increases very rapidly with the density of the traffic. In comparing the two projects it must be kept in mind that the broad channels and duplicate locks make a blockade almost impossible on the summit-level canal, while the narrow waterway of the sea-level canal is far more liable to interruption.'

Lock gate operating.—To open and close the gates a rigid steel arm is attached to each leaf. The arm is forced in and out of a chamber in the lock wall by a fixed pinion meshing into an attached rack bar.

Electric power is provided for, with a hand gear for use in case of breakdown.

Estimates for a direct single stroke hydraulic gate arm were made by Mr. Haycock. (See appendix H), but the expense was too great, and the water would have to be replaced by oil during freezing weather, as is done at the American Soo locks.

The arm for gate operating by electric power was introduced by Mr. Monro on the Soulanges canal, and is far preferable to the wire rope and pulley system.

Every lock is provided with 4 sets of gates—two pairs of upper ones and two pairs of lower ones. Now, take the most dangerous case, a boat entering the lock from above, with both pairs of upper gates open, and suppose that, by accident, she crashes into the first pair of lower gates. They will certainly be liable to injury, but being of steel, they will bend and twist before breaking, and the bow of the boat will have its plates cut and torn open. (See cuts page 71.)

All this will absorb the shock, and tend to sink the boat's bow, so it is hardly conceivable that much damage will be inflicted upon the other pair of lower gates which are 57 feet beyond. This system of double gates has been in use at the Poe lock, American Soo, for many years, and, although boats have rammed the gates,

there has never been a serious accident. Double gates practically obviate the necessity of guard locks. (See page 102.)

A boat bound up that collides with the lower gates of a lock tends to force the gates apart, but, when the lock is full, the weight of water tends to shut them, and the blow being absorbed, the boat is shot back. This actually occurred at the Poe lock, American Soo.

If the lock is empty, and the lower gates open, then an unmanageable boat entering from below will collide with the breast wall of the lock, and never touch the upper gates. (See cuts page 71.)

Long approach piers and double gates of steel, instead of wood, are the safeguards provided to prevent serious crippling at the locks, which, of course, are vulnerable points in a navigation scheme. The only further safety would be to construct two locks side by side; then, one being injured, the other could pass the up and down traffic pro tem.

Lock filling and emptying.—The filling and emptying of locks is accomplished in many different ways. For the large locks at the Soo a tunnel beneath the floor is connected by a movable gate or valve with the upper reach, and when the valve is open the tunnel is rapidly filled, and the water spouts up through openings into the lock chamber.

On the Soulanges canal, Mr. Munro introduced a system similar to that used on the Manchester ship canal, where longitudinal tunnels in each wall are connected by a number of pipes with the lock chamber. Through these the filling water rushes horizontally, the pipes on one side discharging opposite those on the other, so that the currents tend to counteract each other, and the lock fills without commotion and consequent surging of the boat upon its holding lines.

As the lower part of the proposed lock walls are the natural rock, it would be difficult and expensive to excavate wall tunnels; therefore, I have decided to fill from a tunnel underneath the centre of the lock in a manner similar to that used at the Soo. There is this difference, however; instead of filling the culvert at the head of the lock, the water is made to enter at the side, falling through a vertical chamber connected with the central culvert. This obviates strong currents at the head of the locks, which, at the Soo, tend to pull waiting boats away from their moorings.

The governing valves are also simply operated and more easily inspected. The valves at the Soo are 30 feet below water surface, while in this project they need only be from 6 to 10 feet beneath. (See Plate 19A.)

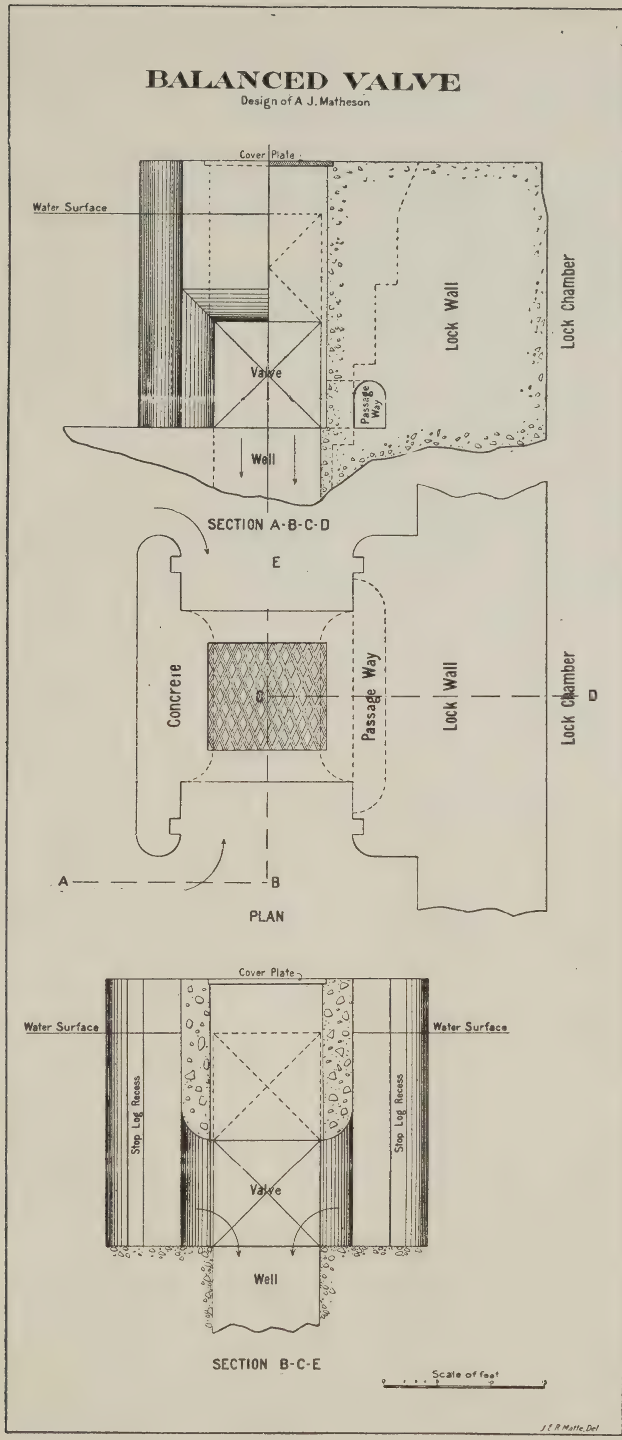
To empty the lock, outlet tunnels with valves will be provided. These valves will be placed just below the surface of the lower reach.

Valves are the movable partitions or gates that throttle or control the flow of water into or out of lock culverts. The ordinary house tap is a valve closing or opening a small pipe, but with the locks of this project the conduits are tunnels 10 feet square. The pressures on the valves in these culverts are very great, amounting in some cases to 150 tons, or over 20 pounds per square inch.

Five kinds of valves are commonly used for locks:

The flap valve, *i.e.,* a trap door of steel hinged to the side of the tunnel and locked by a spring catch agains the weight of water. When the catch is released, the water forces the trap door open and rushes through. It would require great power to close such a valve against high pressures.

A sliding valve is one that slides across the opening like a steel sliding door. The difficulty with this sort is, that the weight of water presses it so firmly against the opening that it drags very hard, unless a net of rollers, ball bearings or wheels are provided to reduce the friction. In the larger sizes for locks the rollers must be of a very hard steel, and the tracks upon which they are run must be mechanically true —a condition that is difficult to maintain under the constant wear of service. The Stoney valve and the coffin valve are of this type also the wagon valve.


BALANCED VALVE
Design of A. J. Matheson
Cover Plate
Water Surface
Valve
Well
Lock Wall
Lock Chamber
Passage Way
SECTION A-B-C-D
E
Concrete
C
Passage Way
Lock Wall
Lock Chamber
D
A
B
PLAN
Cover Plate
Water Surface
Water Surface
Stop Log Recess
Stop Log Recess
Valve
Well
SECTION B-C-E
Scale of feet
J. E. R. Matte, Del.

The drum valve may be compared to a wash-tub turned bottom up and covering an opening. Now, if water stood all over and around the tub, it could not enter the pipe until the tub was raised, when it would flow in all round underneath the rim of the tub. These valves are constructed of steel, and are lifted by a vertical shaft, guide posts being provided for them to slide in. The Fontaine valve is of this kind, and also the Cluett.

The sector valve resembles a buggy top. The convex or the concave side may be placed against the water pressure, and either way the weight is transmitted to its hub, These valves are built up of steel, and work effectively, but are liable to rock from side to side when water is rushing through.

Mr. A. J. Matheson, of this survey, has designed a valve that is perfectly balanced and without moving parts. It is clearly shown in the sketch, page 77.

Lastly, the butterfly type, like a door turning on a central post, or a turn-stile. For these large locks the vertical post is a steel shaft 8 to 12 inches in diameter, to which are attached horizontal steel ribs that support the steel sheeting. The vertical shaft is carried on bearings so that practically no weight is supported by the foot pivot. It is produced up to coping level, and a long steel lever, similar to a tiller, turns the valve like the rudder of a ship. The motor will be set at the end of the arm and engage into a curved rack rail, and thus a great excess of power can be secured.

In the Chicago Drainage canal the whole flow may be held back by an immense butterfly, 184 feet long and 30 feet high, which rotates on a vertical axis. Valves of this type but horizontal have been used on the St. Lawrence canals and at the Soo locks, where they are 8 feet x 10 feet, and operate under 18-foot head. (See Plate 19A.)

After much consideration I have chosen the butterfly valve as having no moving parts and being strong, steady and simple. An operating arm can be keyed directly to the central shaft above the water surface, where it is constantly open to inspection. One-quarter turn opens the valve completely, and it is so solid and strong that ice, chips, and even sunken logs, cannot do it injury.

The time required for a boat to make a lockage is chiefly due to slowing down from full speed and coming to a stop in the lock chamber. This matter was very fully experimented on by the United States Deep Waterways Commission in 1901, and since this, further experiments have been made at the Soo for the Panama Canal Commission by Mr. Ripley; the boiled-down experience being that a lake boat going 12.5 miles per hour will come to a full stop in the lock in a distance of half a mile, *i.e.*, from the end of the guide pier, which extends half a mile above and below each lock. This takes about 8 minutes; to shut the lock gates requires 2 minutes; to fill or empty the lock chamber requires 10 minutes; to open the gates again requires another 2 minutes, and for the boat to get under way and attain full speed, 8 minutes, *i.e.*, 30 minutes in all; but, owing to the caution required with large boats, a lockage is considered to consume 45 minutes from head of pier above to head of pier below, provided, of course, that the boat is not required to wait for a preceding boat.

Lock Electric Motors.—An electric equipment for locks has been reported upon by Mr. Chism in detail. (See Appendix D and Plates 22*a, b, c, d, e.*)

Three-horse-power motors will be used in each case for lock gate operating and for valves. Central operating cabins can be used, but it is probably better to have a motor-man near the gate or valve that is being opened or closed, as unforseen circumstances occur that require action on the spot.

Storage batteries will suffice for all the locks between Montreal and Des Joachims, as electric generating stations are always close at hand to fill the batteries during day time. Three storage units will be placed at each lock sufficient for power purposes and lighting for 48 hours.

Lock Lighting.—Enclosed arc lamps are provided for each lock and the entrance piers above and below.

An acetylene lighting system has also been estimated for by Mr. Haycock. (See Appendix I.)

Lock Mooring Posts, Ladders, etc.—Mooring posts or bollards of cast-iron set in concrete are placed at about 50-foot intervals along each side of the lock, and extend the whole length of both upper and lower entrance piers.

A life-saving equipment is provided for, consisting of ladders set in the face of the lock and pier walls, with chains strung between and railings where required.

Dams to raise Surface and concentrate Fall.

The lock to raise large boats from one channel to another having been described, the type of dam best suited to concentrate the existing river into convenient levels or reaches will be investigated, with a statement first regarding the general project of raising water surfaces.

If an existing stretch, like Lake St. Louis for instance, is over 22 feet deep at lowest water, then no further work is required, but if the lake is only 16 feet deep, then 6 feet must be dug or dredged out of the bottom, unless, happily, the water surface can be raised and kept 6 feet above low water. It generally proves very much cheaper to raise the water surface by building a dam across the outlet than to tediously dredge out a channel; so it has been the aim throughout to raise each reach to high water mark, or as high as the adjacent land will permit.

Moreover, when a channel is dredged, the cost prohibits a wider shipway than 300 feet, but, when the surface is raised, the whole width, or a good part of the width of the lake, is available for a shipway. The more water too there is between the keel of a boat and the river bottom, the faster she will go for the same expenditure of coal, and the safer she will steer. Increased width and depth add greatly to the speed.

When a channel is obtained by raising the water suface, the money expended for damages represents a distribution of wealth throughout the community instead of payments to individuals for work done.

Flat banks with towns, villages or large manufactories, of course, prohibit a rise of surface above ordinary high water as a general rule, but steep, uninhabited shores admit of much higher surface raising, in fact the ancient full bank regime may be reinstated.

Types of Dams.—This raising of the surface is produced by building dams, and a considerable study of types was made to secure a safe and everlasting structure that would for all time obviate the possibility of a disaster like that at Johnstown, Pa., 1890.

Dams may be roughly divided into two kinds; fixed or permanent dams, and movable dams, which can be raised or lowered at will. If it is intended to have water flowing over a dam during flood periods, it must be constructed of timber, masonry, concrete or steel, so that the top edge will not be washed away.

When the water has a means of flowing past the dam instead of over its top, as through sluiceways or conduits, then an earth dam may be constructed with its crest well above the highest possible water surface.

The great earth dam for the Panama canal at Gatun will be 115 feet high, with its crest 30 feet above the surface of the lake it creates, and its base half a mile in width. The foundation is a deep soil, and the dam will be made of dredged mud pumped to place through pipes. During construction, the Chagres river will be passed by a special channel, and only after completion will the water be alowed to collect within. Sluiceways will carry all the tropical floods.

The Ottawa project, however, does not admit of earth dams, because at some points earth is not cheapy attainable in quantity; moreover, earth could not be deposited in a rapidly running stream, and there is no means of passing the river flow during construction.

Cribwork dams have been much used in Canada. They consist of a large box, or succession of boxes, made of timber, and filled with stone until they sink to the bottom. The top is then covered with a timber deck or apron, over which the water flows. Carillon is a notable example. Unless these dams are kept constantly wet, the timber decays, and ice and saw logs passing over injure them continually. The height of this sort of dam is limited to 20 odd feet generally.

They are difficult to place in rapid water, and the cribwork will bridge over holes in the river bed, leaving cavities that cannot be filled.

A concrete dam is becoming very usual, especially for water power developments. The bottom of the river must be laid dry by means of coffer-dams to construct them, and a good foundation must be secured. They are liable to burst explosively during great floods, as at Austin, Texas, or to be scoured under by unseen leakage, and, when long and high, concrete dams are expensive.

Another type of dam is the steel-plate dam. It consists of a sloping steel-plate, upon which the water rests, the supports being steel 'A' frames beneath the tight face. Dams of this type—200 feet in height—are being used in irrigation work through the American southwest. Like a concrete dam, the bed of the river must be laid dry, so that the bottom edge may be attached to the river bed by a concrete base. When the length is great these dams become expensive, and coffer-dams, with the usual uncertainties are required to secure a dry bottom for their construction.

After examining closely into various types, the writer concluded to revert to a simple huge rock-fill, as suggested by him in 1899 for the French river navigation.

The Ottawa river, at the localities where I propose dams, has not only worn its channel through the clay, but has cut deeply into the bed-rock; therefore, there is but little trouble to be expected from scouring. Moreover, the great quantities of rock to be excavated can be at once deposited in the dams, and the work proceed uninterruptedly winter and summer.

It is proposed to stretch a cableway across the river at the dam sites. No coffer-dam at all is required. Loose rock in large and small sizes will be carried out in aerial skips and let fall into the river till a great bank is gradually built up, the water rising with it and thoroughly scouring and compacting the mass until it finds exit through the sluiceways, which will have been previously built for its passage. These sluiceways are of the common stop-log type so familiar to residents of the Ottawa valley.

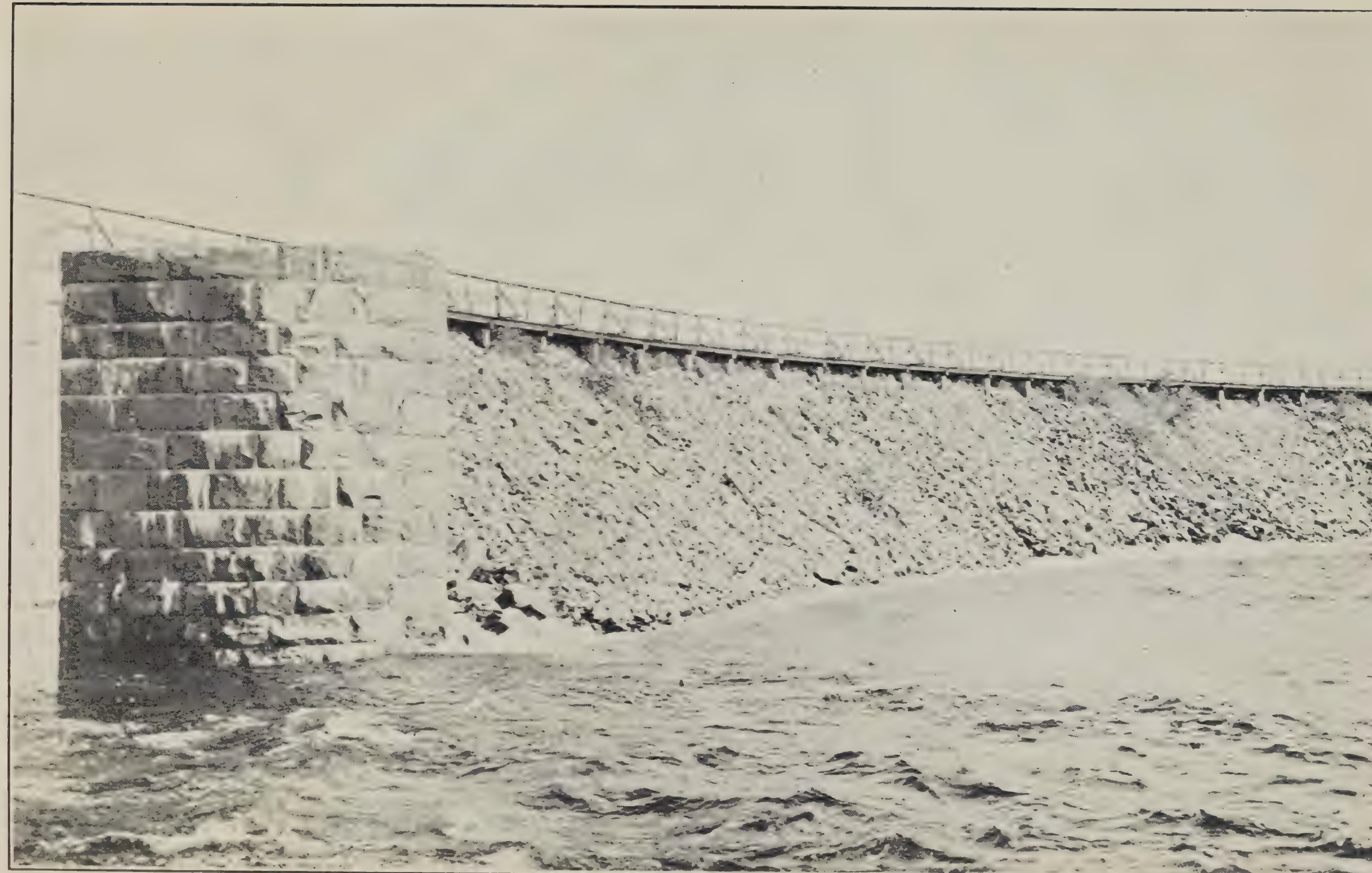
The rock-fill will be enlarged, so that both the upstream and downstream slope fall away one foot vertically in two feet horizontally or at a 2 to 1 slope. The top width will be 20 feet at 5 feet above the water surface. (See estimate plan 24.)

This huge rock bank becomes really a part of the geology of the locality. It cannot overturn like a masonry wall, nor can it slide upon its base. If the river bottom scours out beneath it to any extent, the loose stone settles into the cavity, and if by accident water pours over the top of it, the loose rock will not be eaten away to any great extent. Under no circumstances will the dam burst suddenly, and subject the people below to a disaster like that at Johnstown, Pa.

For the purposes of the project a certain amount of water must pass, and the leakage, therefore, does not represent a loss. If, however, it is desired, the embankment can be staunched on the upstream face, by covering it first with small-sized stones, then possibly with gravel, and finally with a thick layer of earth stretching out on a 3 to 1 slope, and, if necessary, quantities of sawdust or shingle shavings can be used to secure tightness.

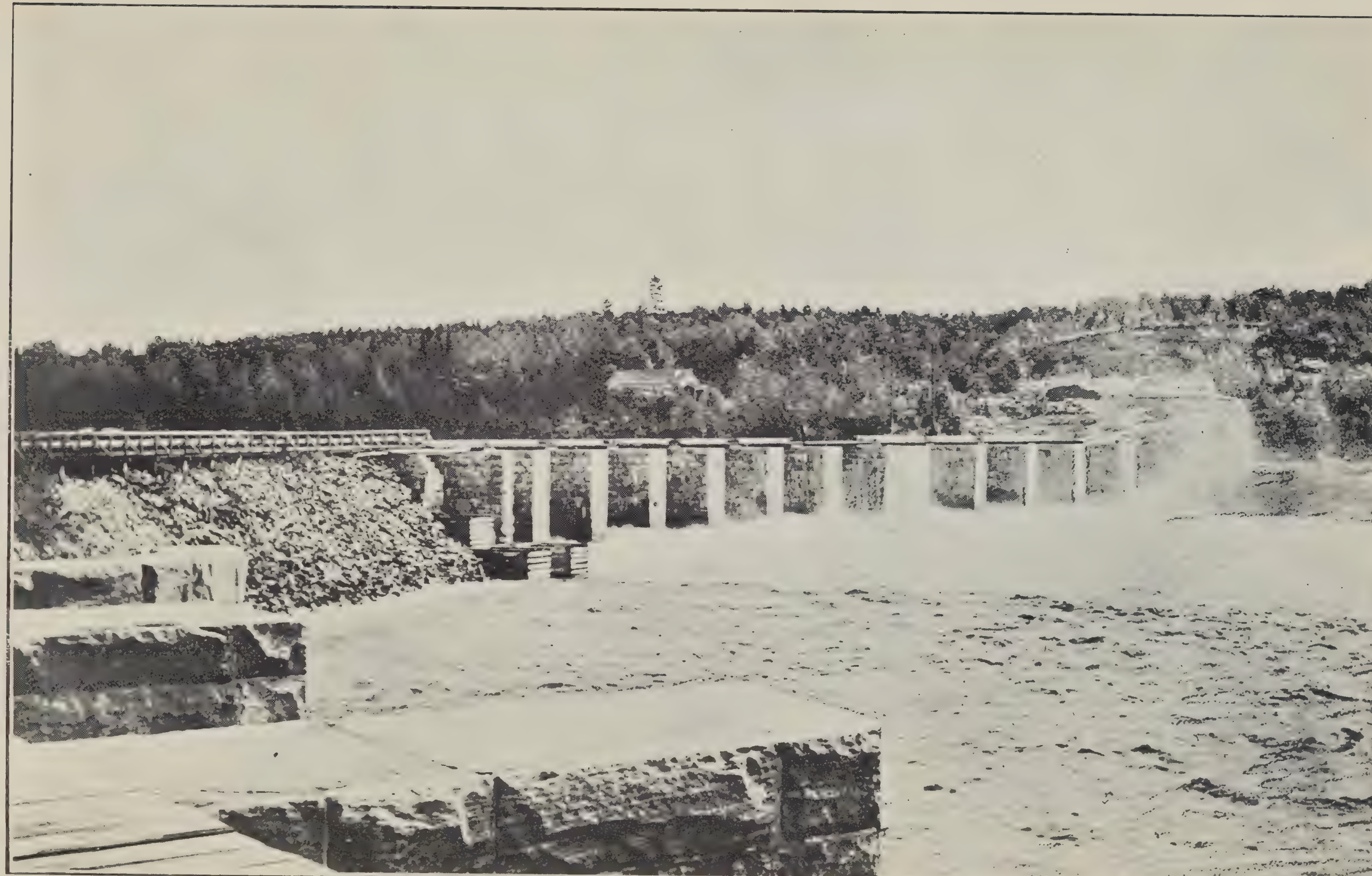
Rock-fill dams are used in India and also in the western states, where, however, a core of concrete, steel or wood is frequently used to secure tightness, as the water is stored for irrigation purposes and every drop is valuable. For our purpose, however, a core of any kind—masonry, concrete, earth, &c., would introduce com-

ROCK FILL DAM, KENORA, ONT.



Retaining 18 ft. of water: top width, 6 ft.: slopes, 1 to 1: fill constructed by dumping loose rock from both sides of river. Notice leakage along toe.

Rock Fill Dam, Kenora, Ont.



View of west regulation sluices connecting with loose rock: bank east side sluices in fore ground: small cribs at center are fish ways.

ROCK FILL DAM, KENORA, ONT.

Stop-log regulation sluices showing lifting apparatus.

plication in construction and be less enduring and less easily repaired than the upstream slope of earth.

There are examples in the mountains of rock slides causing dams; a recent remarkable example being the Frank slide, Alberta, which completely obstructed the Old Man river for a time.

Across the Winnipeg river, near Kenora, is a notable example of a rock-fill dam built by dumping from cars. It was constructed 15 years ago by Messrs. John and Wm. Kennedy, and, at the present day, supports an 18 to 20 foot head. The sluiceways are closed by stop-logs, and altogether it closely resembles the style of dam and regulation that I propose. (See cuts.)

Regulation Sluices for Reaches

Although the dams pen up the river into reaches or lakes, there still exists a constant flow of water not noticeable, it is true, in wide, deep sections, but nevertheless amounting to many thousands of cubic feet each second. This bulk of accumulating water must be given an outlet or the level would fill up and overflow, causing floods and damage.

Sluiceways are provided for this outlet, and a consideration of various matters connected therewith was made. (See Plate 21.)

When water pours over the crest of a dam in a sheet, a foot deep, about 3⅓ cubic feet tumble per second along each foot, and if the crest is 10 feet long 33 cubic feet pass each second if 20 feet long 66 c.f.s., and so on. When, however, the sheet is 2 feet deep, then a 20 foot length of crest passes nearly 185 c.f.s., and a sheet 4 feet deep will pass 528 c.f.s. over a 20 foot length of crest. (See Plate 27.)

It will be seen that the volume increases rapidly as the depth becomes greater. The allowable depth flowing over the dam, however, cannot well exceed 8 feet or 10 feet, because the tons of water falling over produce tremors, and also pound away the foundation on the lower side.

The depth on crest being limited, a great length of crest must be depended upon in order to assure passing a large flow. For the Ottawa project crests from one-eighth to half a mile would be necessary, and as this great length would be necessarily built of concrete or some solid material equally as expensive, another system was sought.

Again, if an overtopped dam were used with, say, 10 feet passing over in flood time, then during low water, only a foot or so would be passing, and the whole surface above would have fallen nearly nine feet; an intolerable condition for first-class navigation.

Large pipes governed by valves are used to regulate smaller reservoirs, but the great volumes to be handled on this project prohibited their use.

Stoney, an English engineer, introduced a deep broad sluiceway, which he governed by a vertical gate that could be hoisted up clear of the water surface, allowing full flow, or it could be dropped down to completely close the opening. Sluices 50 feet wide and 20 feet deep are in service of this style. (See Plate 24.)

Unfortunately, Stoney sluices are expensive, and ice conditions are against their use, in some locations. An estimate for different widths and depths was made by Mr. Goldmark. (See Appendix G.)

A wide, deep sluice was adopted, but closed by stop-logs instead of steel gates. A width of 20 feet was designed by Mr. Matheson. (See Plate 21). And he has also prepared a table of the volume each can pass. (See Plate 27.)

Each dam, then, has a battery of sluiceways to pass the regulated flow of the river and an excess of from 25 per cent to 50 per cent in order to provide for exceptional floods.

To raise and lower the stop-logs, a machine has been designed by Mr. Haycock (Plate 21A.) This consists of a housed-in car, that can be moved along from sluice

to sluice, equipped with gears that operate two vertical ratchet bars simultaneously. These bars press down or lift up one stop-log at a time.

In a few instances, between two canal reaches, where the flow is small but requires to be quickly given twin culverts 6 feet x 6 feet, governed by Stoney valves, are employed. (See Plate 23.)

Of course, butterfly valves, similar to those used in locks, may be substituted for the Stoney valves in these culverts.

Flood Regulation.

It remains to consider the question of flood regulation. There is only one source of water, whether it courses along in rivulets or springs up from the soil, *i.e.*, the rain and snow falling from the clouds.

The Ottawa valley or watershed is bounded toward the north by the height of land or crest of the ridge, which marks the commencement of the slope to Hudson bay. Along the west and south the ridge marks the slope towards the Great Lakes and St. Lawrence. The encircled valley is 55,700 square miles in area, all of which drains through creeks and rivers eventually into the main stream. The rain and snow fall within this area alone has to be considered. (See Plate 3.)

Of the total area, 45,000 square miles lie to the north of the river, and 10,000—practically all in Ontario—to the south. The northern area from Montreal to Mattawa forms a rectangle 300 miles east and west by 150 miles north and south. Roughly speaking, this rectangle is divided in half by the Gatineau valley.

The Western half or Upper Ottawa basin contains the large lakes—Victoria, Expanse and Quinze, which are enlargements of the Ottawa on its way westwards into its north and south-lying expansion—Lake Timiskaming. Here the Blanche and Montreal rivers enter, and the whole continues south to Mattawa.

Mattawa is at the head of the Ottawa channel, so far as this project is concerned, because, above this, the line runs up the Mattawa river and Trout lake to North Bay.

From Mattawa down to Des Joachims—40 miles—the river is rough, plunging down 20 feet at Deux Rivières, 70 feet at Rocher Capitaine and 40 feet at Des Joachims. This will be divided into three ponds or levels, the lowest one ending at Des Joachims, where a single lock steps down 40 feet to the level of Deep river and Pembroke.

The lower Allumette lake will be raised to form part of this level, so that Pembroke reach extends from Des Joachims 56 miles down to Paquette.

At Paquette there is a step down of 20 feet to Coulonge Lake level, which will be extended down the Rocher Fendu channel to Rocher Fendu lock 2. Here there are two steps of 35 feet each, descending to the level of the Portage du Fort reach, ending at Chenaux lock and dam, where another 35 foot drop gains the level of Arnprior lake, reaching down to Chats falls. A drop of 50 feet at Chats descends to Aylmer lake, extending down 32 miles to the locks at Hull, where two locks step down 55 feet to a 60-mile stretch from Ottawa to Hawkesbury lock. Here a descent of 20 feet reaches the Pointe Fortune level, and another of 40 feet gains the level of Oka lake, extending to Ste. Anne. This is the last or lowest reservoir of the Ottawa system.

Now if these levels or ponds were represented by boxes of water set step-fashion, one above the other, and a stream of water flowed into the upper one, then, as the boxes filled, they would overflow step by step into each other, or a square notch could be cut in the edge of each one, through which the spilling would take place. These notches correspond to the regulation sluices placed in each of the dams.

If the supply at the top were very great and the notch could not pass the water, it would rise and flood over the sides of the boxes. If the supply were an insignificant dribble, then the surface in each box would fall, and only very little water pass over

the notch. Indeed, with a bright warm sun, evaporation might lower the water surface below the notch, so that there would be no flow at all.

Fortunately the Ottawa never becomes a dribble; there is always sufficient water for the project, so we are only concerned with high water and extreme floods, as in the year 1876 and the present year, 1908.

Returning to the boxes, the bottom one represents Oka lake. If it overflows, Vaudreuil and the surrounding flats would be badly flooded; therefore, only an inflow which will not overtax the capacity of its outlets can be tolerated. By good fortune, Oka lake has twice filled to just a fairly permissible level during this survey, and the outflow at that stage of water was measured at Vaudreuil, at St. Anne, at Back river and at St. Eustache, and found to be 155,000 cubic feet per second. This, then. is the permissible amount that can be alowed to flow in at the head of Oka lake, i.e., at Point Fortune.

Now Oka lake receives two small rivers, the North river and Rigaud river, which combined contribute, say 3,000 c.f.s. to the lake during May, so it would be more proper to say that only 155,000 less 3,000, or 152,000 c.f.s. could be permitted to flow in at Point Fortune.

The next reach,—Point Fortune to Hawkesbury,—has no tributary, so at Hawkesbury we can still allow 152,000 c.f.s. to pass on.

From Hawkesbury to Ottawa, however, several rivers contribute their quota of drainage.

The combined flow of all these subtracted from the admissible flow at Hawkesbury leaves, say, 90,000 c.f.s., as admissible flow over the Chaudière falls.

In this way the amount of water that can be allowed into the improved river at each point on the way upwards may be determined.

The following list shows the admissible flow that may enter the head of each reach on this project:—

	Admissible flow. Cubic feet per sec.
Out of Oka lake	155,000
Rivers flowing into Oka lake	3,000
Admissible flow at Pointe Fortuné	152,000
Admissible flow into Pt. Fortune reach or past Hawkesb'ry.	152,000
Rivers flowing into Ottawa reach	60,000
Admissible flow at Chaudière	90,000
Rivers flowing into Aylmer lake	4,000
Admissible flow at Chats	86,000
Rivers flowing into Arnprior lake	17,000
Admissible flow at Chenaux	69,000
Rivers flowing into Portage du Fort and Rocher Fendu reaches	2,000
Admissible flow at Coulonge	67,000
Rivers flowing into Coulonge lake	7,000
Admissable flow at Paquette, taken at Spottswoods, includes Culbute flow	60,000
Rivers flowing into Pembroke reach	8,000
Admissible flow at Des Joachims	52,000
Rivers flowing into Mackey reach	6,000
Admissible flow at Rocher Capitaine	46,000
Rivers flowing into Bessitt's reach	1,000
Admissible flow at Deux Rivières	45,000
Admissible flow at Mattawa	45,000

Briefly, this means that the ordinary high water flow of the upper Ottawa may be admitted into the navigation system at Mattawa. This flow, by additions from

tributary drainage, will increase 15 per cent by the time it reaches Des Joachims, 33 per cent by the time it reaches Paquette, and 100 per cent by the time it reaches the Chaudière at Ottawa. (See Plate 26.)

The only flood on the Ottawa is during May and June, when the rapidly melting snows and early rains from the northern districts overcharge the numerous lakes and descend in conjunction to the main stream. The territory is a vast area of archæn granite, filled with lakes of three, six, ten and even twenty square miles area and covered with a dense lumber forest. (See Plate 30.)

The greatest flood was in 1876, when the flow during the third week of May at Mattawa is estimated to have attained 111,000 c.f.s. This flood was due to a heavy snowfall late in April, followed by rains, causing all the tributaries over the basin to pour off in conjunction. (See Plate 25.)

This year (1908) has been the nearest approximation to 1876, but only 87,000 c.f.s. flowed at Mattawa; therefore, it is considered safe, but at the same time necessary, to provide storage sufficient for a year like 1876.

After examination it was arranged to pass not more than about 45,000 c.f.s. through the proposed reach below Mattawa.

The convenient height to keep this Mattawa reach is about elevation 500. At that surface there is one minimum section of 16,000 square feet area, another of 19,000 feet and another 23,000 square feet. Everything considered then, a flow of 45,000 c.f.s. will pass these choke points at a safe and reasonable current for navigation purposes, i.e., well under 3 miles per hour.

Again the 45,000 c.f.s. flow is added to, as has been seen on the 300 mile journey to Montreal, so that 155,000 c.f.s. empties out of the river, and this keeps the lowest reach and the intervening ten reaches all at convenient surface heights.

The first immediate storage necessary is to restrain an extreme flow of 111,000 c.f.s. (1876) from 20,000 square miles, so that only 45,000 c.f.s. will require to be passed during May and June. We have not a discharge curve for 1876, the great flood year, but the following computation of flow that year is considered very ample:—

Suppose the flood to reach 45,000 c.f.s. (regulated flow), May 1, and then to increase steadily to 111,000 c.f.s. (maximum flow, 1876) June 1, and then to decrease steadily to 45,000 c.f.s. (regulated flow), July 1.

At Mattawa—Excess flow over 45,000 c.f.s., May and June, 1876—

May 1 to June 1, 30 days, 45,000 to 111,000; average 78,000 c.f.s.

June 1 to July 1, 30 days, 111,000 to 45,000; average, 78,000 c.f.s.

The flood over 45,000 c.f.s maximum admissible flow averages 33,000 c.f.s. for 60 days.

Excess of 33,000 c.f.s will cover 102 square miles a foot deep in 1 day (24 hours).

Excess of 33,000 c.f.s. will cover 6,136 square miles a foot deep in 60 days (24 hours).

That is, 6,136 square mile feet of storage are required. Now, if a lake of that area (Ontario, for example) existed, it would only be necessary to build a dam and let its surface rise a foot in order to store this surplus or excess flow that occurs during 60 days (May and June).

Even a lake of 613 square miles area would effect the same end, if raised 10 feet. No single lake of anything like 600 square miles exists, but groups of lakes whose aggregate available storage is upwards of 600 square miles do exist. These groups of lakes, fortunately, are so disposed throughout the drainage area as to be low enough to catch the run-off of their particular streams. If a lake be at the head of a river, for example, it cannot catch and hold the run-off of the valley miles below.

The principal main river expansions, with their storage possibilities, are:

——	Area.	Thickness of Storage.	Capacity.
GROUP (1)—	sq. mls.	ft.	sq. m. ft.
Lakes—			
Rabbit, Victoria, Birch	65	11	700
GROUP (2)—			
Quinze, Expanse	100	5	500
GROUP (3)—			
Timiskaming	115	5	600
Total			1,800

It is, therefore, necessary to seek further storage areas on the tributaries of these lakes, in order to get the 6,136 square mile feet required, and, beginning with Timiskaming, we have available:

——	——	Capacity.
GROUP (3)—TIMISKAMING BASIN—		sq. m. ft.
Lakes—		
Montreal river lakes	Estimated available	600
Kipawa, Blanche	Estimated available	1,900
Total		2,500

Adding these—(1,800 + 2,500) we have still only 4,300 sq. m.f. so that (6,000—4,300) 1,700 sq. m.f. more storage must be sought, and, turning to the tributaries of Quinze and Expanse, we find:

——	——	Capacity.
GROUP (2)—QUINZE—EXPANSE BASIN—		sq. m. ft.
Lakes—		
Turnback and Kinojevis	Estimated available	600
Roger	Estimated available	100
Barrier	Estimated available	300
Total		1,000

We must ,therefore, search out storage on the tributaries of Rabbit, Victoria and Birch to the extent of 826 sq. m. ft.:

Group (I.) Lakes above Victoria basin, estimated, 900 sq. m. ft.

Sufficient storage is thus seen to be available, so that even in an extreme year, like 1876, the run-off of which has been purposely exaggerated, it will be possible to manage the upper basin so that during May and June the flow into the Mattawa navigation reach will not exceed 45,000 c.f.s.

It will be seen that storage above Mattawa really amounts to cutting off the so-called 'north water.'

To illustrate this: the past spring (1908) a flow of 75,000 c.f.s. was measured at Deux Rivières, May 19, but with proposed regulation this flow would not have been greater than 45,000 c.f.s., so 30,000 c.f.s. would have been held back from swelling the

flow of the main river on its way to Montreal. The reach itself (7·6 square miles area) has two tributaries, the Maganasibi and Aumond creek; the total drainage area being 460 square miles, so that no flood on top of the through flood is to be feared, therefore it is not necessary to make impounding dams on the tributaries. (Plate 3.)

Rocher Capitaine reach (area 4 sq. miles) has a tributary area of 115 square miles, Bissett's creek being the principal inflow. The through flow leaving the end of the reach will not have increased over 1,000 c.f.s., and the width and depth allow of passing this flow at a very moderate velocity.

Des Joachims reach (area 7 sq. miles) receives the first large tributary, the Du Moine, which is 65 miles in length. The local drainage area of the reach is 1,900 square miles, of which the Du Moine constitutes 1,500 square miles. There are several lakes which equalize the Du Moine flow somewhat, and on May 12, 1908, the northern ones were still frozen, but the lower area had run off. The Du Moine and the local watershed will add about 6,000 c.f.s. to the through flow, so that the Des Joachims sluices are required to pass 52,000 c.f.s. The raised river has ample size to pass this flow at less than 3 feet per second velocity. The reach below to Pembroke has considerable area, so that 10 per cent in excess of the above flow would only raise its level one foot in five days. McConnell lake could be arranged to act as a reservoir also, if necessary.

Pembroke reach (area 75 sq. miles) receives the drainage from nearly 3,000 square miles. Its chief tributaries are:—

River.	Drainage area.	High water flow.
	sq. miles.	c. f. s.
Schyan	300	1,500
Petawawa	1,575	7,500
Indian	440	2,000

This spring (1908) the estimated outflow from the Pembroke lakes into Coulonge was about 100,000 c.f.s. for, say, ten days. Had the proposed storage been in operation, 30,000 c.f.s of this flow would have been held from passing in at Mattawa, therefore, the through flow in Pembroke reach would have been 70,000 c.f.s.

There is a choke section at Morrison island, which will be widened and deepened under the project, so that, in conjunction with the Culbute channel north of Allumette island, there will be an active area of 25,000 square feet. This will suffice to pass 75,000 c.f.s. at 3 feet velocity.

To pass 100,000 c.f.s. the lake at Pembroke is filled to just the proposed surface height, elevation 370, so, with the north water cut off at Mattawa, there is no danger of overflowing the reach. The current would have been slightly over 3 feet per second at Morrison island, not seriously swift, however, but the great trouble would have been a too great flow into Coulonge reach below.

Coulonge reach (area 25 sq. miles) receives the local drainage off 3,100 square miles of basin, as follows:—

River.	Drainage area.	High water flow.
	sq. miles.	c. f. s.
Black	950	8,500
Coulonge	1,820	16,500

During May, 1908, the flow measured at La Passe near the lower end of the lake averaged 128,000 c.f.s. for a week, the water surface being elevation 354. In 1876 the lake stood at elevation 354.7, and the flow at La Passe was 157,000 c.f.s., while 145,000 entered the head. The proposed storage would cut at least 30,000 c.f.s off the flow, leaving 98,000 c.f.s. through flow at La Passe.

There is a choke section at Bryson bridge, and also where the Rocher Fendu empties into its lake, mile 186, the area being:—

Bryson bridge..	9,005 sq. ft.
Rocher Fendu..	14,295 " "
Total area available..	23,300 " "

This will only admit, say, 70,000 c.f.s. at 3 feet per second velocity.

Coulonge reach at working level, elevation 350, will only pass 63,000 c.f.s., but less than a foot rise will allow 70,000 c.f.s to pass. There is a slope from La Passe to Bryson of at least 3 feet, when Coulonge is at elevation 350, and the discharge at Bryson is then about 27,000 c.f.s and at Rocher Fendu, 36,000 c.f.s. Again, although the flow of the Bryson channel may be quickened somewhat, that at Rocher Fendu, owing to reverse curves and the short reach between locks 1 and 2, should remain not over 3 feet per second.

Lastly, Arnprior reach below has a large tributary area, and cannot hold an excess from up river when its own local basin is in flood.

For these reasons it seems expedient to provide storage for 25,000 c.f.s, during, say, 10 days, thereby reducing the flow at La Passe as follows:—

Average flow measured May, 1908, at La Passe.		128,000 c. f. s.
Deduct flow cut off by storage above Mattawa.	30,000 c. f. s.	
Deduct flow cut off by storage above La Passe	25,000 "	55,000 "
Leaving regulated through flow at La Passe..		73,000 c. f. s.

This requires 80 square mile feet of storage for each day, and the available storage so far known is:—

——	Area.	Depth.	Storage.
Black River—	sq. mls.	ft.	sq. mile ft.
St. Patrick lake	10	10	100
Moose Patrick lake	5	10	50
McGillivray lake..	3	10	30
Total			180

Sufficient to store the whole flow for 7 days.

——	Area.	Depth.	Storage.
Coulonge River—	sq. mls.	ft.	sq. mile ft.
Little Victoria lake..	6	12	72
Brulé lake....	8	11	88
Giroux lake	6	10	60
Nishkolea lake..	6	5	30
Big and Dam	7	10	70
Smaller lakes...			175
Total			495

Sufficient to store the whole river for 10 days.

Black and Coulonge combined then furnish enough storage in their watersheds to keep, say 20,000 c.f.s., out of the through flow for 10 days. It will probably be necessary to seek further storage either on the Petawawa watershed or the Du Moine, or on both. The former has probably 600 sq. mile feet of storage and the latter 800. In 1876 the flow was nearly 30,000 c.f.s. greater than 1908, so that to restrain the flow to 70,000 c.f.s. it would be necessary to hold back 55,000 c.f.s. in addition to the Upper Ottawa storage. This would require 170 square mile feet for each day's storage, or 1,700 square mile feet for 10 days, so all the possible storage would be necessary.

Arnprior reach (area 28·5 square miles) receives the local drainage off 5,700 square miles of watershed, as follows:—

——	Drainage area.	High water flow.
River—	sq. miles.	c. f. s.
Bonnechere...	910	6,000
Madawaska...	3,210	19,000
Mississippi (part)...	1,400	(part) 8,000
Shores.	167	....

During May, 1908, the outflow at Chats was about 135,000 c.f.s., and, if 30,000 had been cut off at Mattawa, this would have been reduced to 105,000 c.f.s., and, if 25,000 c.f.s. had been cut off at La Passe, the flow would only have been 80,000 c.f.s.

The head of Chats rapids (mile 156·18) presents a flow area of 29,150 square feet, and possibly this could be increased to 31,000 square feet by reversing the flow of the west outlet of the Mississippi. The regulated through flow of 80,000 c.f.s. could be passed easily, and even 10 per cent more. This flow would not raise the lake above the working stage, elev. 245, nor would it overload Aylmer reach below, as that level is large and receives only a small drainage.

It then appears that no storage is required on the Madawaska, because the storage at La Passe to limit the amount passing Rocher Fendu has so reduced the through flow (to 73,000 c.f.s.) that the combined flow of the Madawaska and Bonnechere do not overtax the height of Arnprior reach, nor its discharging capacity.

Storage on the Madawaska would, of course, be of great value to augment the low stage flow of the main river for power and domestic purposes.

Aylmer reach (area 46.5 square miles) receives only a small local drainage, 650 square miles; the Quio, the Carp and part of the Mississippi being the tributaries.

During May, 1908, the flow at the Chaudiere was about 140,000 c.f.s., Aylmer lake being 3 feet above proposed working stage. Reduced by 55,000 c.f.s., this would have been 85,000 c.f.s., which can easily be discharged when Aylmer is at working level, elev. 295.

Between Deschenes and Britannia is a restricted section, 21,200 square feet area, which, however, could be enlarged to 28,000 by rock excavation on both sides of the river.

The large lakes so far mentioned will be extended and kept at constant level, generally ordinary high surface, but all structures are five feet above this level, so that a four-foot layer can be temporarily stored upon each without stopping traffic. Their storage capacity would be as follows: —

Reach.	Area.	Safe extra rise.	Storage capacity.
	sq. mls.	ft.	
Deux Rivieres..	8	4	2 days for flow 5,000 c. f. s.
Rocher Capitaine.	4	4	1 day " "
Des Joachims.	7	4	2 days " "
Pembroke..	75	4	20 " " "
Coulonge	25	4	6 " " "
Arnprior...	28	4	7 " " "
Aylmer..	47	4	12 " " "

The Gatineau during September and October flows about 5,000 c.f.s., so the table means that Aylmer reach would rise 4 feet if a stream the size of the low water Gatineau were to flow in for twelve days, while Arnprior and Coulonge lakes would last a week and Pembroke reach three weeks under similar conditions.

These reaches would in like time be prepared to pass a 25-foot draft boat, it may be remarked.

Ottawa reach (area 66 sq. miles) receives the drainage off 19,700 square miles, half of which enters at the upper end.

The following list exhibits the character of the chief tributaries.

Name.	Area.	High water flow.	Date.
	sq. mls.	c. f. s.	
Gatineau...	9,200	30—70,000	Middle of May.
Lievre...	4,100	12—30,000	" "
Rouge...	1,800	5—12,000	" "
Rideau.	1,400	: —15,000	April.
South Nation.	1,400	2—18,000	April can be neglected.

The Gatineau and Rideau flow in just above Rockliffe, a narrow section (800 ft.) but fortunately of great depth, so that the current is not prohibitive.

Numerous measurements were made below this junction, and it was found that, with a surface elevation 140, the through flow was nearly 120,000 c.f.s., and this was adopted. When, therefore, 90,000 c.f.s. enters as through flow by the Chaudière, only 30,000 c.f.s. can be allowed to enter from the Gatineau and Rideau.

The Rideau has usually discharged its flood before the middle of May, but this spring (1908) it ran 9,000 c.f.s. during that period. It is of short duration, however, and an allowance of 5,000 c.f.s. seems ample, allowing a discharge of 25,000 c.f.s from the Gatineau.

The Gatineau flowed 63,500 c.f.s. May, 1908, and is supposed to have flowed 70,000 c.f.s. in 1876. To reduce this flow to 25,000 c.f.s means restraining as follows, from daily discharge curve 1908:—

20 days at 8,000 c. f. s. equivalent to	160,000 c. f. s. for 1 day.
10 " 22,000 " "	220,000 " "
20 " 37,000 " "	740,000 " "
10 " 25,000 " "	250,000 " "
15 " 8,000 " "	120,000 " "
Total excess	1,490,000 c. f. s. for 1 day.

To store this requires 4,600 square mile feet, but so far only 2,600 square mile feet are located, sufficient to store about 60 per cent of the total amount, or to store,

say, forty days of the Gatineau's excess flow over 25,000 c.f.s. That would be up to the middle of June, when of course the main river flow would be decreasing and a greater amount could be received from the Gatineau.

This, however, cannot always be counted upon, as the high flow lasts sometimes well into June. (1904 for instance.)

Another arrangement would be to take the through flow over the Chaudière 90,000 c.f.s., and a greater flow from the Rideau and Gatineau, say 40,000 c.f.s., instead of 30,000 c.f.s., making the total inflow 130,000 c.f.s. This would require 2,640 square mile feet of storage, which, as stated above, is known to exist.

The extra foot rise at Ottawa in order to pass 130,000 c.f.s is not objectionable, but 10,000 c.f.s. additional is launched upon the through flow out of the reach at Grenville and onwards. To avoid this overload, storage must be sought upon the basins of the Lievre and Rouge.

This requires 31 square mile feet for each day of retention, and the available storage is:—

	Sq. mile feet.
Lievre, several lakes aggregating..	760
Rouge " "	1,760
Total..	2,520

There is, therefore, enough storage to hold 10,000 c.f.s. for 80 days, and the flow of the rivers as shown above is large enough to be worth while restraining.

Below Grenville there are no tributaries of consequence, the total drainage area to the head of Montreal island being 1,200 square miles, which runs off in April or the early part of May.

A matter of interest is the time it takes the bulk of water to move from Ottawa to Grenville. From observations made towards the end of May 1908 the average speed of flow appears to be 1¼ miles per hour, so about 48 hours after water passes Ottawa it arrives at Grenville. The time from Mattawa to Ottawa is probably nine to twelve days, depending on the height of flood.

CHANNELS.

Even when the water surface is raised there are still canal cuts to make and shoals to be excavated in order to secure a 22-foot channel for boats.

The excavation consists largely (6,327,000 c. yds.) of wet rock, that is, rock which must be drilled and blasted or pounded to pieces under water and then removed by dredging. Practically all of it is limestone.

Wet earth or loose material beneath water varies through all classes of soft sands or clays and hard gravel, cobble and boulder material. The former may be removed by suction dredge, but the latter require a dipper dredge, and are much more expensive to remove (c. yds., 8,400,000).

Dry rock has not been considered such an expensive material since the building of the Chicago canal. Explosives have been cheapened and steam excavators are now used to remove the broken rock at the rate of 100,000 c. yds. a season. (See page 94.) Much of this rock will go to make up the dams (c. yds., 8,860,000, of which 5,700,000 lime and 3,160,000 granite). See page 326.

Canal cuts are the chief localities from which dry earth will be excavated. Soft and hard materials are encountered, and in some localities the haul from pit to place of disposal will be two to three miles.

Some of the canals above locks will be carried in side embankments, and to prevent current in the narrow 200 foot channel the side banks must not leak to any extent. Crib-face has been provided for in some cases and concrete core walls in others.

The side slopes of all excavations in earth, boulder material or friable rock are set, two horizontal to one vertical (2 to 1). In good solid rock a vertical face is proposed; in rock or earth, however, whether the sides show above water or are hidden beneath the surface, permanent piers will mark the bottom width. Steel boats will not, therefore, tear their plates along the sides. (See plate 37.)

In all cases, too, the center line of channel will be shown by range lights.

Along canal cuts or wherever an earth-face is exposed to wash of waves, a heavy protection of stone is provided to prevent erosion. (See plate 37.)

The curves, which occur in dredged portions, are nearly all over a mile radius, but in eight cases curves as sharp as half a mile radius, and in three cases one-third mile radius are used between Montreal and Des Joachims (see plate 35.) All curved channels are widened on the outer side.

As there will be practically no current, boats should make equally as good time as in the dredged channels of the St. Mary's river (width, 300 feet), viz., 9 miles per hour and 6 miles per hour in canal (width, 200 feet). The time of passage is given at the end of the detailed description of each reach.

DAMAGES.

A raised surface system, of course, results in flooding property which must be bought, and from Montreal to Joachims $3,000,000 will be expended. Two-thirds of this sum are incurred from Hawkesbury to Aylmer, 70 miles in length, where large flats, that are nearly flooded during May and June, will be kept continually so. (See detail description, pages 106 and 110.)

The only developed water powers that are completely destroyed are those at Deschenes rapids, and by the creation of a power at the Hull dam an equal amount of current might possibly be returned.

At Montreal, provision is made for replacing the water power used for pumping the city's supply during the summer months, including the passage of the supply main beneath the navigation channel. (See detail description, page 94.) The Lachine, Hawkesbury and Ottawa intake pipes are also arranged for. (See detail description, pages 95, 106 and 110.)

Drainage difficulties are fortunately not formidable. The sewerage of Verdun will require a pumping plant. (See detail description, page 94.)

At Hawkesbury an outfall sewer is to be passed beneath the canal, and at Hull a culvert is arranged to pass the tail water of the city power-house.

Railway and highway bridges and diversions amount in all to over a million dollars. In all cases where traffic is likely to increase, double tracks have been provided for. The Victoria bridge crossing at Montreal, the Canadian Pacific railway bridge at Lachine, and the Grand Trunk and Canadian Pacific bridges at St. Anne amount to half the whole expenditure required. (See page 93, 96 and 98.)

DETAILED DESCRIPTION OF PROJECT BY REACHES.

The following is a detailed description of the project from Montreal westwards:—

The mileage is counted from the Custom House, Montreal. Eastwards from this point the St. Lawrence ship channel is, of course, used to Quebec. (See Plates 4 and 4A.)

There are two projects to be considered—one leading up from Lachine through Lake St. Louis and Ste. Anne to Oka, called 'the front line,' and a back line branching from the St. Lawrence ship channel, 17 miles below Montreal, near Cap St. Michel, and proceeding up the Back river past Sault Recollet, Carterville and Ile Bizard to Oka.

Considering the front line first: The creation of a slack water navigation is accomplished by forming a series of pools connected by locks. Montreal harbour is the starting pool, and the question is, what height shall the first step be?

La Prairie basin, just above the Victoria bridge, is subject to a winter flood caused by the accumulation of ice This flood has attained a level so high as to inundate St. Gabriel, and some years ago a protection dike was built along the river front to prevent this. This dike extends from the Victoria bridge, Point St. Charles, along the shore two miles to Verdun, and its top is 52 feet above the sea, *i.e.*, elev. 52.

Now this dike has protected the inhabitants for some years from high water. It is reasonable to propose that the dike, which is nothing else but a rough earth mound or dam, be raised, enlarged and strengthened, and that a portion at least of La Prairie basin be kept permanently at flood level, elev. 52.

I, therefore, propose to cut off a bay of the river between Nun's island and the dike by a long embankment extending up in prolongation of the Mackay pier from Victoria bridge to Nun's Island and on to opposite Verdun hospital—a bank 4 miles long. which contains three-quarter million cubic yards of earth, forming a core, and covered inside and out by a cap of loose rock requiring 1¼ million cubic yards. Between this bank and the shore a lake of water, generally over 22 feet deep, will be formed, through which boats may go at full speed. (See Plate 4.)

The east end of this basin will be closed by a lock and dam, situated at the foot of Bickerdike pier, and extending across to Mackay pier. This is just about the head of the deepened harbour, but a short dredged channel will be required below the lock to allow 20 feet draft to enter.

MONTREAL LOCK.

This lock, like all the others, is 650 feet between the upper and lower gates, and 65 feet wide. The length over all, from end to end, is 846 feet. It is founded on flat bed rock, chazy limestone, the surface of which is elev. 20. Now the low water of Montreal harbour is elev. 18, and we require 22 feet below this, which makes the bottom of the channel 4 feet below sea level. This elevation is taken as the bottom of the lock. It does not seem necessary to keep the entrance channel a foot lower than the lock bottom; in fact, 22 feet is the depth of channel, and many would consider that the lock bottom should be made 1 foot above the channel outside; but why manufacture this obstacle when it is unnecessary, and the extra foot beneath the boat is always advisable? The pit or excavation for the lock is, therefore, sunk 20 odd feet into the bed rock. (See Plate 38.)

The lock pit could be blasted out in the usual manner some 100 feet wide, and the side walls be built full size from the bottom up, but why blast away the solid rock and then replace it with concrete at great expense? The pit is better, therefore, carefully cut out with smooth sides a few feet larger than the width of the lock, and its sides faced with concrete, 3, 4 or 5 feet thick, the case requires. A thickness of 5 feet has been assumed throughout, to ensure full estimation for the filling of crannies and voids that may be found between the beds of rock. (See cuts page 71.)

The sides of the pit are cut out by a channeling machine, which is a large steel chisel operated like a steam drill, that makes a slot about 3 inches wide all around the pit. The rock within this channel slot is then drilled, blown and removed without injury to the sides.

The surface of the rock is practically dry in summer, and only a small dam around the pit will be required, but a bulk sum for unwatering, which includes pumping and the removal of snow and ice, is allowed at each lock.

The rock blasted from the lock pit will be disposed of immediately in building a rock-fill dam across to Bickerdike pier, and the rest piled to one side to be used for the concrete of the lock walls themselves. (See Plate 39.)

As soon as the pit is excavated, moulds will be set up, and the construction of the lock walls begun. As the solid rock itself forms the great bulk of the side walls, it will be on'y necessary to build them up from rock surface elev. 20 to coping level elev. 57, a height of 37 feet, which means that material and time will be saved in this manner.

As before mentioned, there is a channel to be excavated below the lock. This amounts to 177,000 cubic yards, which will swell to twice its size, or about 300,000 cubic yards, as loose rock. This will be used to fill the approach pier below the lock, and also that above, leaving still 200,000 cubic yards to be used for the embankment forming the south side of Montreal reach, to which place it will be hauled, either by a temporary railway or possibly scows.

It will take one season—May to December—to excavate the lock pit 75,000 cubic yards, from December to April the site will be covered with 20 feet of water. The next season the lock could be completed by building 60,000 cubic yards of concrete, and putting the gates in place, so that the Montreal reach might be finished in two years.

While the lock is building, the bascule bridge, to allow of crossing the Grand Trunk railway, leading on to Victoria bridge, could be constructed. This bridge has been a matter of consideration. There are 100 trains per day passing the spot, besides the highway traffic. The bridge would, of course, be erected without delaying traffic, by the usual methods.

By the adoption of the bascule type, similar to the many railway bridges crossing the Chicago Drainage canal, Buffalo creek and other places, it is thought that very little delay to traffic will result, as these bridges can be operated so quickly. A point in their favour is their safety, as when open, the leaf stands up vertically, blocking the railway and exhibiting an unmistakeable danger signal. This type of bridge also does away with the central pier necessary for swing bridges, and, in this case, the clear channel is 160 feet wide, which is ample space for two boats 65 feet wide to meet each other in, if necessary. The highway traffic will be served by bascule bridges on each side of the double track railway bridge. (See Plate 34.)

Near the Victoria bridge there is a culvert beneath the Mackay pier. This will be enlarged and modified to form a regulation culvert for the basin.

Between Victoria bridge and Verdun, the south embankment of Montreal basin, four miles in length, will be formed of earth, protected on the river side by loose rock. The rock excavated from Verdun lock-pit and just below it, will furnish enough rock to protect the bank from there down to Victoria bridge.

It would would take one season's (May to December) work of two steam shovels with their haulage outfit of cars and locomotives, to excavate Verdun lock-pit and the entrance below.

The earth required to build the south bank of Montreal basin must be hauled from the Verdun canal cutting, a mean distance of three miles. (See Plate 4.)

Earth from the Verdun canal must also be hauled about three and one-half miles to make up and strengthen the Verdun and St. Gabriel dikes along the north side of Montreal reach.

About two million cubic yards of earth are available for these embankments, so they may be made of full size.

The time required to complete Montreal reach depends upon the excavation of the Verdun canal, as the embankments are made up with this excavation. Five years is estimated, as is explained in the description of St. Louis reach that follows.

The work of a steam shovel during one season—May to December—is usually considered as from 100,000 to 150,000 cubic yards in earth, and in excavating and loading blasted rock modern heavy shovels do just about the same amount.

A modern example of steam shovel capacity in rock work is the excavation lately completed (1907) in the West Neebish channel for the United States government.

Three steam shovels were employed removing the rock as it was blasted out. Their united output was 40,000 cubic yards to 55,000 cubic yards per month, measured in the solid. Four channellers were employed cutting smooth sides, and six to nine steam drills per shovel bored the holes for explosives.

In all cases it is not the excavating power of the shovel, but the transportation service to carry away the material from the steam shovel that is the real limiting factor of the output.

A troublesome feature of this project is that the raised water level drowns out the tail-race of the Montreal city waterworks, or rather the part of the works which is operated during the summer time by water-power. This would leave only the steam pump plant, which alone will not suffice for the growing needs of Montreal. It is, therefore, proposed to build a power-house near the Verdun lock, and use the 18-foot head there either to pump directly by an intake pipe reaching out to the foot of Heron island, about one and one-half miles, where a supply whose purity would be beyond suspicion could be obtained; or else to use the power-house for generating sufficient current, which would be delivered at the present settling basin to run the pumps electrically.

There is also another water supply that would be injured, that of the Montreal Water and Power Company, whose intake will have to be extended out a mile across Nun's island into Laprairie basin.

Further difficulty is encountered with the drainage of Verdun and that brought down the old river St. Pierre. The most straightforward method of handling this seems to be a pump plant, which might receive power from the proposed power-house at Verdun lock.

The cost of this reach, including bridges and pump plant, is four million dollars. If a through cut had been made from Montreal harbour to Verdun, only 200 feet wide, it would have cost over six million dollars, so that the basin project is cheaper and secures a basin nearly two square miles in area for an upper harbour.

Summary of Disposal of Excavation—Montreal Basin.

Excavation—

177,000	c. yds. rock	below Montreal lock
75,000	"	Montreal lock-pit.
252,000	"	solid measurement.
	say 500,000 c. yds. loose rock.	

Disposed of in building—

Dam, Montreal lock, loose	95,000	cubic yards.
Concrete lock, loose	60,000	"
Crib filling lock, loose	120,000	"
For waste or disposal along Mackay pier	225,000	"

Time to navigate—

Lock	0.75 hours, Montreal lock.
Five miles at 6 m.p.h.	0.80 hours, basin.
	1.55 hours.

LAKE ST, LOUIS REACH.

This consists of the Verdun canal cut, 3 miles long, to the Waterworks' intake, then an embankment canal along shore 2 miles up to Lachine, then 15 miles through the north part of Lake St. Louis to Ste. Anne. (See Plate 4.)

The reach begins with a lock similar to the Montreal lock, which lifts boats about 18 feet. The rock surface at the lock site is elev. 50. So 20 feet in height of the chamber then will be solid bed rock, and the walls will be extended up 25 feet in concrete. (See Plate 39.)

The canal prism above the lock averages 20 odd feet in depth, and is 200 feet wide at bottom and 290 feet at water surface. The side slopes being, as everywhere else, in earth 2 horizontal to 1 vertical. Altogether the canal excavation consists of 3 million cubic yards and 2½ million cubic yards of rock.

The first operation will be to begin the excavation by wheel scrapers, and build up the canal banks where the water surface will be above ground level. Just above the lock a cheap reservoir can be obtained by embanking a triangular area, and these banks would be built at the same time by scrapers.

This basin will act as a compensator above the lock, and prevent excessive currents through the canal when the lock is being filled. It will also act as a head basin to the proposed power house to replace that of the Montreal City Waterworks.

When the canal banks have been built, steam shovels will be put into the cutting, and of the material they excavate, two million cubic yards will go eastwards to build the embankment to Nun's island and the Victoria bridge.

The remainder of the canal excavation will go westwards from the waterworks' intake to form an outside embankment along the foot of the high Lachine river bank. At first only a sufficient bank will be constructed to keep out the water of the St. Lawrence river.

The space between this partial bank and the shore will then be pumped dry, and the excavation of the channel bottom begun. This amounts to nearly two million cubic yards of rock, which laid dry in this manner may be excavated for $1 per cubic yard, but if drilled and excavated beneath the water, it would cost three times as much. The rock from this channel excavation will be used to protect the outside of the embankment all the way up to Lachine. See page 325.

The rock in the Verdun canal cut, lying beneath the earth excavation, amounts to half a million cubic yards. Part of this will be crushed and used in the concrete of the lock walls, and part for filling the long piers above and below the lock, and also for the protection of embankments.

Broken rock is very much needed in canal construction, as already outlined, for concrete, and for the strengthening and protecting of earth banks. It is also required in considerable quantities to protect earth banks along the canal water line, where the ripple from winds and the waves of passing boats are constantly tending to eat away the earth slope. Much has been written regarding this bank protection, and many costly experiments have been made. It is the writer's opinion that broken stone forms a good protection if it is laid on a very flat slope, say, 4 horizontal to 1 vertical, instead of 2 to 1, which is the usual practice. A cubic yard of broken stone per foot forward has been estimated for at a cost of $2 per cubic yard in place.

There is a sharp quarter bend at the Waterworks' intake—mile 8—necessitated by the abrupt turn of the river bank. The outside bank of this portion is subject to a not very severe wash from the St. Lawrence river flowing along its outside edge, but it may be subjected to considerable tearing from float ice. For this reason, it is proposed to protect it heavily with loose rock, great quantities of which will be excavated in the vicinity. (See Plate 4.)

The present intake of the Montreal aqueduct must be preserved, if, instead of pumping direct at the proposed power house, the old pumping plant is electrically driven. To secure this a double conduit is provided beneath the canal, with a valve house at each end. This, of course, can be constructed before other work is begun obviating any nuisance from muddy water during building operations.

At Lachine also the intake pipe must be extended out beneath the canal in a conduit. Although so many intake pipes are disturbed by the proposed canal, still,

in each case, their extension is further out into the river into deeper water, ensuring the best quality of water obtainable in the locality, and, owing to the inlet being deeper, less nuisance from anchor ice.

The drainage outlet for Lachine and the various towns between it and Verdun is not affected by the canal project, as this nearly all tends into the Little St. Pierre river, the flow of which will be handled by the proposed drainage pumps at Verdun.

Sluice at Verdun Lock.—At Verdun lock a sluiceway is necessary to regulate the supply of water into the basin below. The structure here used is simply two parallel culverts 6 feet wide and 7 feet high situated beneath the dam barring the end of the reach. These culverts are throttled by sluices, which are operated through a concrete shaft or well extending up to the top of the bank. This syle of regulator was designed by Mr. J. L. Allison, and used extensively on the Soulanges canal. See Plate 23.

This reach is crossed by the Canadian Pacific railway bridge below Lachine, at mile 9½. It is proposed to construct a bascule bridge, giving a clear width of 160 feet for boats to pass. As this bridge is high,—30 feet clear,—many tugs will be able to pass beneath it without opening. The bridge is estimated for two tracks, although at present only a single track structure exists.

Just below Ste. Anne there is a quarter bend which, however, is in deep water with good width. The lower entrance to Ste. Anne lock has been made of extra width, as the discharge from the regulating works at that place may produce cross currents, and the greater width will assist boats in navigating. (See Plate 40.)

There are already two small locks at Ste. Anne, only one, however, being used. This one will remain intact during construction, so that navigation will not be impeded. It will be understood, also, that the Lachine canal navigation will not in any way be interrupted during construction.

As to time of construction, the lock at Verdun can be constructed in two seasons. From the Verdun canal cut 5 milion cubic yards are to be excavated.

If ten steam shovels are set to work, the earth from five being hauled eastwards and from the other five west, then it would take about five years to complete the cut and make the banks and levees down to Victoria bridge and upwards from the aqueduct to Lachine. It will take about the same time to excavate the channel bottom from the aqueduct to Lachine.

In Lake St. Louis there are about 2 million cubic yards of rock and 2 million cubic yards of earth between Lachine and Ste. Anne,—a distance of 14 miles. This would take eight dredging plants 5 years to accomplish, and the excavation would form a bank 60 feet wide along the whole distance. Unless dumping in the deep lake is allowed the disposal of the material is a troublesome question. (See Plate 4.)

At Lachine, Lake St. Louis itself is entered, and the line for 3 miles follows the dredged channel of the St. Lawrence, which is 16 feet deep below at low water. To obtain 22 feet, it will be necessary to deepen the existing channel 6 feet, all of which excavation, unfortunately, is in solid rock; in fact the best route that can be selected between Lachine and Ste. Anne necessitates very heavy excavation both of rock and earth,—two million cubic yards of each,—and the rock being altogether under water will cost $3 per cubic yard.

The north part of Lake St. Louis is shallow, and it is not possible to escape this heavy excavation. In addition to this, the water surface of the lake fluctuates from elevation 66 to elevation 72, because there are no regulation works at its foot. This necessitates excavating a depth sufficient to give 22 feet at low water.

If the surface of Lake St. Louis were maintained at a constant elevation,—70—then a very material saving in excavation could be effected, not only through Lake St. Louis itself between Lachine and Ste. Anne, but also through the channel below Lachine to and through the Verdun canal, for the higher surface of Lake St. Louis would be produced down into the Verdun canal.

It is the writer's opinion that a regulating dam could be economically placed across the St. Lawrence in the vicinity of the Canadian Pacific railway bridge.

Better still, and much more far reaching in indirect benefits, would be a large rock-fill dam across the Lachine rapids at Heron island, from the north to the south shore. A lift lock and regulating sluices could be founded in solid rock on Heron island, and, the plane of Lake St. Louis being produced down to the dam, a slack water navigation would be created. (See plate 4.)

The effect of slack water would be that the whole surface of Lake St. Louis down to the dam would be covered with ice early in the season instead of remaining open all winter from Dorval down. The formation of anchor ice would thus be prevented, and the disastrous floods in Montreal harbour and below would cease.

This scheme would also require a dam across the river between St. Lambert and the city, with regulation sluices, which would hold La Prairie basin at a constant elevation of 45. An earth dike around the south shore of La Prairie basin would protect the land in that vicinity now flooded every winter, and keep it dry and available for factory sites.

A steamer ascending the river then from Montreal harbour would lock up into La Prairie basin, pass through the Victoria bridge, and have five miles of unimpeded navigation through the artificial level to Heron lock, where another rise of 25 feet would bring her directly into the Lake St. Louis level, and she could proceed either up the St. Lawrence route to Cascades, or by the Ottawa project to Ste. Anne.

The two dams at St. Lambert and Heron island would furnish enormous water-power, absolutely secure from interruption by anchor ice.

This scheme could be constructed for five million dollars, as compared to sixteen million dollars for the other, and the benefits conferred would be vastly greater.

Two lines were estimated, using the present Lachine canal in part, but their cost and the difficulty of keeping various traffic routes open during construction caused their abandonment.

Summary of Disposal, Verdun Canal Excavation.

Excavation—Earth—

2,960,000	cubic yards	earth,	canal.
25,000	"	"	lock pit.
2,985,000	"	"	

Excavation—Rock—

130,000	cubic yards	rock,	Verdun lock pit.
70,000	"	"	below "
450,000	"	"	Verdun canal.
650,000	"	"	solid, or say 1,200,00 cubic yards loose rock.

Embankments—Earth—

	C. yds. earth.
South bank of Montreal basin, across Nun island to Victoria bridge	1,500,000
North bank, Montreal basin, increasing Verdun and St. Gabriel dike	300,000
Bank, sides Verdun canal	300,000
Bank outside Lachine shore	200,000
Waste	600,000

Embankments, &c.—Rock—

	C. yds. loose rock.
South bank protection, Montreal basin	250,000
Bank lining inside Montreal basin	50,000
Bank lining inside Verdun canal	40,000
Concrete, Verdun lock	60,000
Waste	800,000

Time to navigate—

Lock	0·75	hours,	Verdun.
5 miles at 6 m. p. h.	0·80	"	Verdun canal.
14 " "	1·60	"	Lake St. Louis.
	3·15		

OKA REACH.

At Ste. Anne a lock is required to step up to Oka lake. It is of the same length and breadth as the other locks, but the lift is very much less, being only 5 to 8 feet, so that bed rock forms 20 feet of the height of the chamber wall and the remaining 16 feet of the wall is built up in concrete. Above and below the lock are the usual guide piers. The lock is located on the site of the old Ste. Anne lock, which will, therefore, be destroyed, but, as mentioned before, the navigation will continue to pass through the other lock as at present. (See plate 40.)

Over the lock the double-track bridges of the Grand Trunk and Canadian Pacific railways cross at nearly right angles, and 30 feet above. Each of these bridges will require bascule draw-spans, in fact there is not room for a turning-span to revolve in.

Oka lake is the lowest of the ponds formed by the Ottawa river. It has five outlets—at Vaudreuil, Ste. Anne, Cap à L'Orme, the Lallemand and St. Eustache. At each place regulating sluices are required to govern the outflow. During springtime all, or nearly all, the sluices would be opened, and as the flood subsided, they would be gradually closed down to summer régime, so that the level of the lake would be kept practically constant at elevation 75. If the surface of the lake were held at elevation 80, a troublesome condition might be created, although during the flood of 1876 it was fully up to that level for a month or so. The lower elevation—75—has been chosen as being ordinary high water, but all the structures are sufficiently high to allow of a 4-foot rise over this height, or elevation 79, in case of necessity. (Plates 4 and 4 A.)

The shores of Oka lake are subjected to considerable erosion by wave action during the summer, but it will not be necessary to attempt any stone bank protection, as nature has already adjusted the slope of the beach.

The southerly side of the lake is generally clay soil, while the north is sandy, especially from Oka to St. Eustache.

The Vaudreuil outlet is 1,500 feet wide. During January and February the rise of water in Lake St. Louis, due to anchor ice, causes a flow of St. Lawrence water northward through this channel into Oka lake, whence it finds an outlet by Ste. Anne and the Back river. It is, therefore, necessary to form a movable dam at Vaudreuil, which may be taken out after navigation closes. A stop-log dam appears suitable to meet these conditions. It has been located just above the Canadian Pacific railway bridge, and consists of a foundation platform of concrete placed upon the natural rock to level it up and, upon this concrete base, piers are constructed, with spaces of 20 feet between them. Over the top of the piers is a service bridge, and the openings are closed by horizontal stop-logs, which will be moved and piled upon the bridge every winter, so that the St. Lawrence water may flow through in the contrary direction.

At Ste. Anne the width is 800 feet, but half of this will be occupied with navigation works, leaving about 400 feet for sluices, which will be similar to those at

Vaudreuil. Unfortunately, the flow from these sluices will create a cross current in the ship channel. During navigation, however, as little regulating as possible will be done at this point. In winter all the sluices will be left open to accommodate the St. Lawrence flow. (See plate 21.)

At the other three outlets similar sluiceways are provided for, and in all cases a rock foundation has fortunately been secured.

There is rock excavation for a mile above Ste. Anne lock, and then mixed excavation for 3 miles further, when there is deep water for 10 miles up to Hay island.

The heaviest excavation on this reach is that above Ste. Anne, amounting to 130,000 cubic yards of rock. The lock pit itself,—42,000 cubic yards, will be easily dammed off and excavated in the dry, and, although a part of that above may be treated in a similar manner, it has been estimated as dredging. This rock, and the 800,000 cubic yards of earth dredging between Ste. Anne and Cadieux island, will require two dredging plants five seasons to excavate. The material—nearly a million cubic yards,—could be deposited in the deep water,—40 feet,—near by. (See plate 5.)

At Hay island nearly a million cubic yards of clay are to be excavated. It can likely be taken out by hydraulic dredging, as it seems very soft, and be deposited by pipe line between Paquin island and Carillon island.

At this point Oka lake ends, and the river.—half a mile wide, is followed for 8 miles without interruption to near Point Fortune.

Just below Point Fortune there is a shoal in mid-channel, which must be removed to secure a good entrance to the lock.

The soft material at Hay island could be excavated by a suction dredge in two or three seasons, and the shoal below Pointe Fortune,—150,000 cubic yards,—half of which is rock, would take one or two seasons.

Front route—Time to navigate:—

Lock.	·75	hours,	Montreal, (see page 94).
5 miles at 6 m. p. h.	·80	"	Montreal basin.
Lock.	·75	"	Verdun.
5 miles at 6 m. p. h.	·80	"	Verdun canal.
14 miles at 9 m. p.h.	1·60	"	Lake St. Louis, (see page 98).
Lock.	·75	"	Ste. Anne.
5 miles at 9 m. p. h.	·50	"	Ile Cadieux,
19 miles at 12 m. p. h. . . .	1·60	"	Pt. Fortune.
	7·55	"	

BACK RIVER LINE.

ST. LAWRENCE SHIP CHANNEL TO PRAIRIES LOCK.

The line leaves the Montreal Quebec ship channel near Varennes, and proceeds due west through the soft river bed for 8 miles to Prairies lock, apposite the small village of Rivières des Prairies, which is 5 miles higher up than Bout de L'Ile.

Channels are provided to allow of either up or down bound traffic from the ship channel entering the Ottawa. (See plate 4 A.)

The surface of the St. Lawrence at Bout de L'Ile is elevation 16 at low water, and this surface continues up to the Prairies lock; therefore the channel bottom is (16—22) elev. 6. The width of the channel is 300 feet, widened at curves. This necessitates the excavation and disposal of four million cubic yards of material, which is generally a soft clay that can be excavated by suction dredges and pumped away through pipes. It can be deposited upon the islands at Bout de L'Ile, and the upper portion of the channel excavation may be disposed of on Macheu island without incurring the risk of its running back into the channel.

The excavation coud be done in three seasons. The Canadian hydraulic dredge *J. I. Tarte* excavated during working season of 1907, and removed by pipe line, 2 million yards of material in the St. Lawrence below Montreal.

The line passes through Ile Bourdon in 35 feet cut, and this material will prove harder excavation than the channel below and above, although a good part of it can be done dry.

At this point the Chateauguay and Northern railway (Great Northern) is crossed, and a bascule doube track bridge has been estimated for, leaving a clear waterway of 160 feet. About mile 8 the excavation becomes rock and continues so for the next half mile up to Prairies lock.

The line is generally direct, but bends, none of which are sharp, are necessary at four places to get between the numerous islands. Each leg is provided with range lights and mark piers so as to render navigation fully as easy as in the ship channel.

At mile 5 the St. Eustache branch or Mille Iles river joins the Back river, but without appreciable current. The manufacturing town of Terrebonne is situated 11 miles up this branch.

The end of Montreal island, (Bout de L'Ile), is a triangular flat, elevated about 35 feet above the sea for a distance of 2 miles. The ground then runs up quickly to elevation 75, and continues to rise toward Mount Royal. Examination failed to discover any practical crossing between Bout de l'Ile and St. Anne—the west end of Montreal island.

To cut through the island and join the St. Lawrence ship channel at the head of Ile Ste. Therese would be somewhat more expensive than the route as estimated. The saving in distance between the short cut and the adopted line Montreal customs house would be about six miles in distance but nothing in time of transit owing to reduced speed through canal cutting.

PRAIRIES REACH.

The lock or step up to this reach is located on the north shore opposite Des Prairies village, its lift being 24 feet, from surface elev. 16 to surface elev. 40. A greater rise than this would flood the village property, and the damage might be considerably increased by the erosion of the soft earth banks along the south side. (See plate 4 A.)

The Prairies lock is founded on rock, the surface of which is elev. 20 so that the walls for 26 feet in height are formed in the natural bed-rock. The remaining 25 feet in height of wall are built in concrete in a similar manner to all the other locks. About 43,000 cubic yards of concrete will be required for this, and part of the lock-pit excavation can be used. (See plate 38.)

The usual guide piers are provided above and below the lock. The upper guide pier forms a side wall to a short canal along the river bank.

There is a rock-fill dam between the lock and the south shore, which will require 100,000 cubic yards of loose rock.

The rock excavation immediately below the lock can be dammed off and excavated dry at the same time as the lock-pit, and will furnish ample material for the filling of guide piers and the dam.

Stop-log sluiceways are provided in the dam to pass the flow of the river. There are 14 openings each 20 feet wide, and capable of passing 20 feet depth of water, and even 24 feet depth if the reach above should rise by accident. The regulated flow through Back river is 65,000 c.f.s., and 25 per cent additional is provided.

About a mile above the lock a straight channel will require the excavation of about 21,000 cubic yards of rock, which can be taken out dry.

Further up the channel, about two miles above St Vincent de Paul, nearly 850,000 cubic yards of rock excavation is required extending right to the foot of Recollet lock—mile 17.

This heavy rock excavation is necessary so as to enlarge the river bed and prevent a current swifter than four feet per second for the total flow of 65,000 c.f.s.

The river now flows with considerable current, but with little depth, a rough limestone bed-rock. The proposed raised surface or working level will just obliterate the sloping fall of the river past Visitation island, and so destroy the current, without increasing the depth. It will, therefore, be necessary to increase the size of the river. To accomplish this a channel 700 feet wide will be taken out south of Visitation island to allow a flow of 10 feet in depth. This can be excavated dry. Part will be earth, 54,000 cubic yards, and part rock, 202,000 cubic yards. The village property destroyed is often flooded, and so no great damage will be done. This channel could be excavated by three shovels in two seasons, working winter and summer. (See plate 4 A.)

The navigation channel north of Visitation island is full 300 feet wide, and excavated 7 feet into the rock river bed for a distance of about 1½ miles below Recollect lock. This can be closed off by dams from shore and excavated dry, especially as most of the river flow will be passed south of Visitation island. Three seasons will be required to complete this channel, that is, one season after the channel south of Visitation island is finished. The water surface at Prairies lock will be raised about 15 feet and extend level to Recollet lock, where the surface will be as at present. There will be 368 acres of land inundated. The north bank from St. Vincent de Paul upwards is very steep, and the south shore is fairly high, but it may be necessary to protect parts of is by a stone slope, ample rock for which is available from the excavation.

A small water power at Prairies lock will be extinguished, and also that between Ile Visitation and the south shore, where a small cardboard factory is now in existence.

RECOLLET REACH.

Recollet lock is on the north side, a mile below Pont Viau, the lift being 35 feet, which attains the level of Oka reach. It will be noted that only two locks are required to rise to Oka level by the Back river, while the front line requires three locks, as a small lift seems absolutely necessary at Ste. Anne. (See plate 4 A.)

Recollect lock is founded on solid rock, the surface of which is elev. 40, so that the bottom being elev. 18, 22 feet of wall is in solid rock, leaving 40 feet to be built up in concrete. (See plate 38.)

Below the lock is the usual cribwork approach, and above is the lock cribwork pier. This is backed by earth from the canal excavation to create a dam across the small gulley just above the lock, which then forms an entrance basin about a mile long.

This expansion of the surface will diminish the bore or wave which travels down a narrow canal during and after the filling of a lock, tending to slam the upper gates shut just when they are in progress of opening.

Above the lock—mile 17 to mile 28—are 11 miles of canal, and the question of a guard lock at the head and a guard gate just above the Recollet lock, comes up.

A guard lock at the head of the canal, where it enters Oka lake, would be subject to the drive of the waves down the lake, which would prevent the opening of the upper gates, as has been experienced on the Soulanges canal at Coteau under similar conditions.

On the other hand, without a guard lock, winds are apt to pile the water in the narrow canal towards the foot. This action nearly resulted in overflowing the banks

of the Welland canal at Thorold during a gale down Lake Erie. The gates of the Port Colborne guard lock had been left open, and could not be shut owing to the heavy waves that ran in from the lake.

Again, the carrying away of the lock gates at Recollet lock or a break in the canal bank would create a swift current through the canal, and a lowering of the surface that would wreck steamers navigating the reach.

The sides of the canal have been designed 5 feet above Oka lake, which is sufficient to obviate any danger from the piling action of the water toward the lower end of the canal.

Recollect lock, like all others on the route, has four pairs of steel gates. Both the lower pairs are always shut against a descending boat, and it is beyond all human probability that a thin steel boat cutting into the 4 foot wide girders of these steel lock gates would completely carry away the pair 57 feet below. The bows of the boat would be cut in, and she would remain hanging in the wreck of the first pair of gates, forming a very effective dam. (See page 73.)

Near the head of the canal at Bigras island a large area of sluices is provided, that empty directly into the river channel, which at this place is rock. If then the canal bank should give way at any point, these sluices will be opened and the greater part of the flow from Oka lake will discharge through them. Only a small quantity would tend to continue down the canal, and, therefore, a temporary dam could easily be constructed across the channel below the sluices till the break in the bank was repaired.

In this connection it must be remembered that, even with a guard lock, the whole contents of the canal would tear out through any break in the bank and do practically all the damage that could be done.

I have, therefore, made no provision for guard lock nor guard gates, but have preferred to place full confidence in the Bigras island sluices.

The Recollet canal necessitates over five million cubic yards of dry earth excavation, and half a million cubic yards of rock. The standard size of embankments amounts to three million cubic yards, so that a good margin is left to widen and strengthen the usual cross section.

There are several bridges to be dealt with. Viau bridge traffic will be carried across at Recollet lock. (See plate 4A).

For the Canadian Pacific Railway a bascule bridge is provided at Parc Laval—mile 19.

The Cartierville road traffic will be crossed by a bascule bridge in the same line as the present road.

The highway traffic to Ile Bizard can pass along the south bank, as a roadway is provided over the Bagras sluices.

Along the whole 11 miles of canal it will be necessary to protect both sides by broken stone against the wash of boats, etc.

Above the canal, the channel toward Oka village will be dredged, 7 feet deep, through the shallow sand flats at the east end of Oka lake—mile 28 to mile 37—a total excavation of 4½ million cubic yards, most of which can be handled by suction dredge.

Silting in of this channel, with sand by wind storms, is liable to occur, but the powerful suction dredges now in use are capable of rapidly and cheaply clearing it away.

The time required for the construction of the Recollet reach and Oka lake section would probably be five seasons if 12 steam shovels, or their equivalent, were employed in the canal section itself—mile 17 to mile 28. The dredging in Oka lake can be completed in advance of this.

Back river route—Time to navigate.

9 miles at 9 m. p. h.	1·00	hours,	ship channel, Cap St. Michel.
Lock	·75	"	Prairies.
6 miles at 10 m. p. h.	·60	"	river.
2 miles at 9 m. p. h.	·20	"	river.
Lock	·75	"	Recollet.
11 miles at 6 m. p. h.	2·00	"	canal.
9 miles at 9 m. p. h.	1·00	"	Oka lake shoal.
20 miles at 12 m. p. h.	1·70	"	Oka lake deep.
	8·00	"	

POINTE FORTUNE REACH

At Point Fortune there is a rise of 40 feet, elev. 75 to elev. 115—which is attained by one lock and 2 miles of canal. (See plate 5).

The lock is founded in rock for the first 20 feet of its height; the remaining 45 feet of the walls will have to be made in concrete, the quantity of which will be 85,000 cubic yards. (See plate 5).

The canal above the lock is 200 feet wide at the bottom, with vertical sides in rock and marking piers to define the edges. The excavation amounts to 400,000 cubic yards of rock and 1¼ million cubic yards of earth.

To raise the water surface high enough, a large dam is necessary near the head of the canal at Dewar island.

There is already a dam across the river at the head of the Carillon canal. It was built in 1882 of cribwork filled with stone, but the current scoured out the shale rock beneath the cribs, and as the rock filling was not loose, but held in the cribs that bridged over the holes, it was necessary to reconstruct it during 1883.

The Dewar island dam will be a rock-fill nearly 50 feet in height, the base of which will be over 200 feet wide and in direct contact with the rock bottom of the river, so that if scouring takes place, the loose rock will settled down into the hole.

It is, of course, very desirable to deposit the rock into this dam as it is excavated, but, unfortunately, in this case the river must be kept open for navigation, so it will be necessary to place the excavation in a large spoil heap near the dam site till the canal and lock are completed; then by commencing to build the dam, at the close of navigation, from the spoil heap, the river surface above can be raised to elev. 100, at least, before the opening of navigation. This will allow boats drawing 7 feet to pass through the new canal and lock, and the dam can be completed during the summer.

It will take 400,000 cubic yards of rock to form the dam to standard section, but as there is a large surplus of rock, it may be used to reinforce the dam, although it is quite unnecessary—the proposed section being much beyond the requirements of the case.

Regulating sluices will be placed upon the rock surface of Dewar island; the usual stop-log type being quite sufficient and when the upper level reaches elevation 100 it will begin to pass through the sluice openings and be under control. If the May and June flood flow over the dam during construction, no harm will result, as the mass of rock fill will not wash out to any serious extent. If desired, the up-stream face of the dam may be covered with a heavy earth slope to render the whole structure water-tight. (See estimate plan 24.)

A considerable area of farm land will be destroyed by the raising of the water level, for about 3 miles above the head of the canal on the south side.

Above this—mile 53 to mile 57—the river is a rock canyon about 1,000 feet wide, and not very deep at some places, especially at Chute à Blondeau, where

rapids originally existed, but which were just drowned out by the Carillon canal. It is, therefore necessary to raise the water surface very considerably, in order to obtain a sufficiently large area of flow to pass the spring water with a less current than 4 miles per hour. The critical section is about mile 55¾, but fortunately there is a depth of 40 to 70 feet, and the river widens immediately above and below.

From the head of the canal—mile 52 to mile 58—there will be no excavation, but from this point to the next lock—2 miles—the slope up of the river bottom necessitates deeper and deeper excavation, which, unfortunately, is largely rock under water—an item that is always expensive.

Excavation begins about 1½ miles below the Hawkesbury lock, but the cutting is only about 2 or 3 feet till within a mile of the lock, whence the depth runs from 6 to 10 feet. The entrance pier below lock is on the north or river side of the channel, and by building it before excavation begins, and extending a coffer dam down-stream, it may be possible to do the work in the dry.

At Point Fortune lock a road bridge of the bascule type is provided, which will give access to the land north of the canal, and lead to a possible road across the river on top of the dam.

Both sides of the canal will require stone bank protection, but it is not likely that the sides of the artificial lake above will need protection to any great extent.

The regulation sluices on Dewar island must be sufficient to pass practically the whole flow of the Ottawa, as they are the throat through which 50,000 square miles of its drainage area must pass. Of course the contributions of the principal tributaries above Pointe Fortune are always to be considered as partially held back in artificially created reservoirs during May and June. A flow of 150,000 c.f.s. is provided for, and, as stop-log sluices of moderate height are not very expensive, a number more have been provided, so that a flood of 50 per cent in excess of the proposed regulated flow could be passed in case of accident to the regulation works above, etc. The sluices consist of a thick concrete floor placed directly on top of the rock, and, on this platform, piers 6 feet wide are built. Between the piers stop-logs 20 feet in length are placed. (See plate 21.)

The time of construction is dependent upon the excavation in the canal itself, from which about 1½ million cubic yards are to be taken. Five steam shovels will do this in three years, and during another season the dam could be made from the spoil bank as already described.

At Greece Point, the foot of the present Grenville canal, there is a swift current, and here the only ice jam on the Ottawa takes place. These conditions, however, will be completely removed by the raising of the water surface.

This vicinity is the reputed site of Dollard's defense in 1660.

Time to navigate.

Lock....	.75	hours, Pte. Fortune Lock.
2 miles at 6 m. p. h......	.30	" canal.
6 " at 12 "	.50	" river deep.
2 " at 6 "	.20	" river dredged.
	1.75	"

OTTAWA REACH.

From Hawkesbury to Ottawa is one stretch. During the May and June flow there will be 5 feet difference in level or slope in the 60 miles. The river during the progress of the survey was found to have this slope from actual measurement; that is, when surface was elevation 140 at Ottawa, it was elevation 135 at Hawkesbury. This represents the head or fall necessary to force the water of the river through at the proposed regulated stage. (See plate 6.)

The channel bottom is arranged to give full 22 feet depth throughout, that is elevation 135 less 22 feet gives elevation 113 for canal bottom at Hawkesbury, and elevation 140 less 22 feet gives elevation 118 as canal bottom at Hull, the rise being distributed throughout the distance.

The slope will exist till autumn, when, with low water, the flow will not be so fast, and, therefore, will not require so much slope to drive it through.

Now, by closing the sluices at Hawkesbury, the water surface can be maintained at constant level at Ottawa, but there will be less fall and, consequently, a greater height of surface at the lower end; in fact, the surface of this long reach will become almost level, like that of a long, narrow lake. Everything at Hawkesbury, therefore, must be designed of sufficient height to resist a level surface of water produced down from Ottawa. The regulated surface at Ottawa will be elev. 140 (nearly 18 feet on the bottom sill, Rideau canal locks).

In view of these circumstances, the Hawkesbury lock is built to raise boats from elev. 115 to elev. 140, *i.e.*, 25 feet. It is one and one-half miles below the mills founded on rock, the surface of which is elev. 115, so that 22 feet of the chamber is in solid rock, and the walls are produced up 30 feet in concrete, requiring 62,000 cubic yards. (See plate 41.)

Above the lock is a river flat, which will be converted into a small lake by an embankment along the river shore, extending one and one-half miles up to Hawkesbury mill pond; while at the lower end a dam extends from the lock to the steep hillside, which represents the ancient bank of the river. Through this pond a channel 200 feet wide and about 15 feet in depth will be excavated, amounting to 875,000 cubic yards of material, most of which is rock. The embankment will be formed by scraper work from the earth overlying the rock; this to act as a water-tight core, on each side of which will be deposited the excavated rock for weight and protection.

When rough rock is used along the inside of a canal bank, steel boats are liable to have their sides and bilges torn by the sharp edges. To avoid this, small cribwork piers are provided at intervals along the toe of the slope, which will ward boats off the rough stone. (See page 91.)

The dam to maintain the upper level is at the head of the Long Sault rapids, and extends from Grenville south to Hamilton island. This site was chosen as affording a solid rock foundation. (See plate 6.)

Owing to the narrowness of the river, it is necessary to make the whole dam a succession of stop-log sluices in order to pass possible floods, and the rock surface, fortunately, lends itself to this style of construction. It will be necessary to make coffer-dams for the structure in rapid water, but, as each sluice is built, the coffer-dam surrounding it can be cut away and the river allowed to flow through. In this way no great construction difficulty is anticipated, although the site is at present a widely rushing rapid.

Hawkesbury is a flourishing town—the largest between Ottawa and Montreal. One of the chief industries is the large saw-mill of the Hawkesbury Lumber Company. This will not be interfered with by the proposed project, although the steam freighters will pass through the head pond of the mill.

Instead of floods endangering the company's plant for six weeks in the year, and wasting the supply of water, which is needed in the autumn, the scheme will give a head pond regulated to a higher level, and will conserve the water supply by restraining the spring flood. The raised surface without currents will give more space and greater convenience in storing the rafts of logs to be sawn.

Several bridges are required. First, a crossing for the Great Northern railway, which is a high level bridge, base of rail being 34 feet above the proposed water. A double leaf deck bascule is estimated for giving a clear opening for navigation of 200 feet. This is the clear width provided on the Chicago river.

A second crossing is required for low level railway tracks to the mills, and for wagons employed by the company. This is secured by a double leaf through bascule bridge alongside the Great Northern, but at the level of canal bank, the clear span being 200 feet. As only occasional shunting will be done over this bridge, a plank floor upon the ties is provided, which will allow teams to cross at sufficiently frequent intervals.

Both sides of the channel through the mill property are faced with cribwork, and between the canal and the town the low land can be raised and made valuable by depositing excavation from the channel.

As the canal prism crosses the supply main of the Hawkesbury waterworks a double conduit with valve house at each end is provided for in the estimate.

A thorough survey was made for three routes along the north side of the river. One following the shore, one paralleling the present Grenville canal and one passing in rear of Grenville village. The deep channel immediately above Grenville was an attractive feature, but the rocky headland projecting to the river bank prohibited the inland lines and the rocky shore rendered a side line crooked and of doubtful durability, while it would have encroached somewhat on the river bed. (See Appendix B, p. 417.)

For two miles above Hawkesbury mills it will be necessary to dredge out a channel amounting to one and one-half million cubic yards, half of which is rock under water. Above this, all the excavation required for a 22 foot channel to Hull and Ottawa—58 miles—is less than one million cubic yards.

From the end of the Hawkesbury dredging—mile 64 to mile 87—the river channel is very deep, 70 feet and over, and beyond this the river bottom may be described as a series of submerged lake basins, six in all, which are separated by alluvial bars. These lakes are generally 40 feet in depth, and, fortunately, in only four places do the bars between them rise above the required bottom plane of the channel.

The first point is mile 93, near Parker island, where the channel crosses the river from one long, deep lake to another. The next is mile 110, opposite the Little Blanche river; then mile 114, opposite Templeton light, and, finally, mile 118, at the head of Kettle island. The bulk of the material will be soft dredging, and it may be disposed of close at hand.

Although the proposed water level of this reach is only the ordinary high water level, yet considerable land will be flooded, *i.e.*, land which is now every year inundated from four to six weeks will be kept inundated for a whole year.

The first serious inundation is at the mouth of the Calumet river, where the mud flats created by this river and its larger neighbour, the Rouge, are generally inundated each spring. The trouble is very much increased owing to the large lumber manufacturing plant situated on this low land. There is a large surplus of earth excavation in the Hawkesbury entrance near at hand, but it would be an expensive matter to transport this material from the dredges by scows and then transfer the scow's load ashore. Of course, the property is subject to a greater height of flood than this project will create, but it is not subjected to it for more than a few weeks, and a special arrangement will have to be made in case of construction.

Above this there is no particular damage done till Montebello—mile 79—is reached. The town itself is not flooded, but from this point upwards to East Templeton—mile 115, say 35 miles—the north shore of the river is an alluvial flat about a mile wide, bordering a steep slope, which has formed the ancient bank of the river. These flats have been formed of the silt carried down by tributary rivers—the Gatineau, the Lièvre, the Blanche at Thurso, and the North Nation at Plaisance.

This action is made manifest by an examination of, say, the Gatineau river, where deep coulees, carved out of the clay, attest the enormous quantity of silt that has been carried out from the district in the past.

The flats are intersected by long bays, parallel to the main river, which furnish very desirable shooting grounds, and so have been purchased by various game clubs. There is a heavy growth of swamp elm on this low land, and the roots of the trees are

covered by a foot or more of water during May and June. The proposed water surface, however, will remain about these tree roots the whole year, and as a consequence, they will be destroyed by frost and ice.

It will, therefore, be necessary to buy this low land and cut down the trees to prevent their falling into the water and becoming a menace to navigation, because a steel boat is easily punctured by floating or partially submerged timber.

Portions of the south shore are also submerged in like manner, notably below Wendover, at the mouth of the South Nation, and above and below the town of Rockland. The low islands between Rockliffe and Wendover will be covered, and also the Petrie islands, 5 miles above Cumberland, and the shore behind them will be flooded, also Goose island, opposite Templeton, and the lower part of Kettle island.

These shallow inundations or drowned lands make navigation dangerous at night, because there is no clearly defined bank to steer by. Each sailing course is, therefore, marked by range lights, and, in addition, dolphins, or clusters of piles, are provided at intervals to define the edge of the channel; the channel width in all cases of dredging being 300 feet.

The upper end of this reach—mile 119—between Gatineau Point and Rockliffe is narrow, only 800 feet in width. Fortunately, there is no restriction of flow at this place, owing to the great depth—70 feet.

From Gatineau Point the channel continues direct into the mouth of Brewery creek, where the excavation for the Hull locks begin.

The time of construction for this reach depends upon the completion of the Hawkesbury canal, where, including the channel above, about 2 million cubic yards have to be excavated. Three dredges and three steam shovels will complete this in about three years' time, during which period the lock and the regulating dam between Hawkesbury and Grenville can easily be constructed.

Time to Navigate.

Lock	·75 hours,	Hawkesbury.
2 miles at 6 m. p. h.	·30 "	canal.
2 " 9 "	·20 "	river dredged.
29 " 12 "	2·50 "	" deep.
27 " 9 "	3·00 "	" shoal.
	6·75 "	

HULL REACH.

A location in the valley of Brewery creek has been chosen, after considering a number of other routes. The site of Hull city is a rock flat, encircled toward the north and west by two terraces or huge steps which extend to the abrupt shore of the river at Squaw bay, above the Chaudière falls. (See Plate 7.)

The first Hull lock makes a rise of 28 feet up to the first step, and the second lock rises 27 feet to the step above. (See Plate 42.)

Another scheme was to follow the main channel of the Ottawa direct to the Chaudière falls, where a step up would be made on to Table rock. This would, however, necessitate navigating the gorge below the falls, where it would be difficult to control the current. Besides this, a reconstruction of the cantilever bridge would be necessary, as, although it is 60 feet above the water, the masts of lake boats are 125 feet, therefore a drawbridge of some kind would be necessary.

I have also considered the cutting away of Nepean point to allow a draw-span at the south end of the bridge, and then to proceed up the old timber slide channel.

Here again, a boat is confronted with a dangerous current, and, moreover, milling interests are interfered with, and the works necessary would be complicated and expensive.

Hull Lock No. 1 is founded on limestone rock, the surface of which is elevation 150, so that 30 feet of the chamber is in bed rock, and the remaining 20 feet in height of wall is concrete.

Above lock No. 1 is a basin, which curves rather sharply to make the direction required for lock No. 2. The lower end of this basin is in cutting, but the upper portion crosses Brewery creek, which is a rock gorge. This necessitates a bank 25 feet high on each side to carry the canal across. Beneath the bottom a concrete culvert is provided to pass the water of Brewery creek, which at this point is the tail race of the Hull waterworks.

The sides of the canal must be water-tight to prevent loss of water from the small basin, and concrete core walls will be required on each side, with a heavy rock bank to give stability and weight. A similar construction has been very successful in the extension of the Chicago Drainage canal.

At the head of lock No. 1, a bascule railway bridge is required to pass the Canadian Pacific railway lines. The existing railway lines will have to be diverted and rebuilt for a total length of 6 miles. Traffic from Ottawa will then cross at the lock and proceed over Brewery creek to join the main line to Montreal or to turn west and follow the north side of the canal to Squaw bay, where the present Pontiac line to Waltham will be joined. Passing over the same bridge at lock No. 1, a junction with the Gatineau Valley line will be obtained, and a line along the south of the canal will give access to the Chaudière railway bridge. In all cases the grades will be improved.

Time to navigate.

Lock No. 1..	·75	hours, Hull.
¾ mile..	·25	" canal.
	1.00	

AYLMER REACH.

This reach extends from Hull lock No. 2—mile 122—up to Chats lock—mile 156, in all 34 miles.

Hull lock No. 2, situated near the railway station, is in rock, the surface of which is elevation 190. 45 feet in height of the chamber wall is in solid rock, leaving only 10 feet in height to be built of concrete. (See plates 7 and 42.)

To the south of the lock is a regulating culvert, through which a proper supply of water can be passed to the reach below. The lower reach is less than a mile long, and each time lock No. 1 is filled, it would draw down the reach 1 foot, were a supply not provide from above.

Lock No. 2 makes a rise of 27 feet. Above the lock is a canal nearly a mile long, that leads straight to Squaw bay. It is 200 feet wide. The first half is in 20 feet cutting, but the upper part is as deep as 40 feet. Most of this is rock excavation, amounting to half a million cubic yards.

At Squaw bay is the Chaudière dam. This is a great rock fill, stretching across the river to Merrill island, and thence following the chain of islands to Mechanicsville. In the deepest portion of the river the dam will be 80 feet in height. Its top is 20 feet wide and 5 feet above the upper surface. At water level the dam will be 40 feet thick, and it will increase in thickness 4 feet for each foot in depth; so that at the river bottom it will be 300 feet wide. The rock excavated from the canal cut above Hull lock No. 2—½ million cubic yards in the solid, will amout to 1 million cubic yards of loose rock, and the dam as described requires only half of this quantity. It can, therefore, be widened and thickened with the surplus rock, so as to pass a double track railway and a magnificent highway side by side on its top.

There is no chance that this immense rock mound can be overturned, pushed bodily along the river bottom or scoured away. It becomes a part of the geology of the locality, and the population below are in no way endangered. (See page 80.)

This dam will hold up the water surface to the level of Aylmer lake; i.e., the surface plane of Aylmer lake will be produced downward to the dam, obliterating the Deschenes rapids, the Remicks and the Little Chaudière; so that a boat leaving the Hull canal has plain sailing for over 30 miles up to the Chats.

The rock excavation from the Hull canal will be hauled to the river's edge and the dam constructed by end dumping. In the meantime, the sluices on Merrill island and the Ontario shore will have been constructed, and when the water surface reaches these sluiceways the regulated flow, equivalent to ordinary June conditions, will pass through under control. The Chaudière water powers will remain as at present, excepting that the head race will be maintained at constant level throughout the season. The sluices will be founded upon rock, and be of the stop-log type used with such great success in the vicinity of Ottawa. A power apparatus will be provided to operate the stop-logs.

Leaving the Hull canal, a quarter bend is necessitated to gain mid-channel of the river, but, as the water is very deep and the current and regulation sluices are well over to the south side, there will be no difficulty in navigation. (See Plate 7.)

Between Deschenes and Britannia, the rock bar forming the present rapids will require removal. Now, as the drowning out of these rapids has destroyed the current without increasing the depth of water, it is necessary to enlarge the river by excavation in its bed in order to let the June flow pass at a less speed than 3 miles per hour. This increase of the river bed is obtained by widening the navigation channel to 500 feet instead of the usual 300 feet. The excavation amounts to nearly $\frac{3}{4}$ million cubic yards of rock under water. The same results could be obtained by excavating a side channel through either Deschenes or Britannia village, but an enlargement of the central channel confers a benefit to navigation for all time.

Two miles above Deschenes is a quarter turn in wide, deep water, which indicates the corner of the Laurentians, around which the river sweeps. The line then follows a succession of deep-water ponds up to Crown point—mile 147—where 25,000 cubic yards of soft dredging are necessary, and just above this, Twelve Mile island—mile 149—are 300,000 cubic yards of soft excavation, whence there is deep water to Hudson point—mile 153. Here begins the dredged approach channel to the foot of Chats lock, through Pontiac bay, amounting to one-half million cubic yards, two-thirds of which is rock under water.

The only bridges to be provided for on this reach are at Hull lock No. 2. The steam railways have already been provided for by a bridge at Hull lock No. 1, but the canal intersects the Aylmer road and the electric railway to Aylmer. It is proposed to divert the Aylmer road and the electric railway, side by side, along the north side of the canal to join the Chelsea road. An under-crossing will be provided in line of Brewery street, by which they will pass beneath the Pontiac railway, and they will cross at the foot of Lock No. 2 on a bascule bridge and continue along Brewery street to Main street. (See plate 42.)

As a large amount of lumber is manufactured at Ottawa, the question of passing saw-logs and pulp-wood down the river during construction and after the waterway is in operation will be taken up here. For years saw-logs have been floated down the Ottawa in booms, without rafting them together in any way. Arriving at the head of a rapid, the boom has been opened, and the logs allowed to plunge over the chutes in a haphazard manner. At only a few points have log slides been built, and the square timber slides have fallen into decay, only two rafts having passed down during the last ten years. The saw-logs, drifting over the rapids, have piled in heaps on rocks and islands during low water, and the high water of the spring fails to float them all off. Many logs have become water-soaked and float in a vertical position, the end projecting just above water, or perhaps floating unseen just beneath the surface.

These 'dead-heads,' as they are called, could not be endured in a navigable channel, where they would be a constant menace to steel boats moving at full speed. When the waterway is open, logs cannot be allowed to float loose on its surface, for, besides

endangering the skin of the boat, they may be threshed in by the screw, breaking the propellor blades and injuring the machinery. It will, therefore, be necessary to raft the logs in some form and pass them through the locks, like tows of barges.

At Ottawa, however, passing them through the canal would bring them below the falls, instead of above, where they are now received at the mill. It will, therefore, be necessary to provide a small lock for the passage of the rafted logs into the basin above the Chaudière dam.

During the construction period, which will last from three to five years, special arrangements will be necessary to pass the logs down to the various mills. It is thought that lumbering operations will be very much changed after the waterway is completed, and that logs will be sawn much nearer to the localities where they are cut, and the lumber shipped by barge or by rail.

A lock could be constructed on Young's island for about $150,000, which would serve to pass rafts of logs, or barges loaded with pulpwood or other raw material to the Chaudière mills. This, however, is not included in the general estimates, as conditions cannot be foretold.

The project between Ottawa and Chats necessitates the flooding of considerable land, and water powers will also be destroyed. A portion of the village of Tetreauville will be covered by the new water surface, and above this, on the north side, the steam railway and the double track electric road to Aylmer will be covered from one to five feet in depth for about three miles, as they are just along the toe of the side hill which forms the major bank of the river. These tracks might be raised by the material from the Hull canal, but it will be cheaper to rebuild the railway lines, which are parallel and close together, along the side hill just spoken of. About four miles of track will be affected. (See plate 7.)

On the south shore the Canadian Pacific railway will be submerged between Skead's mills and Britannia, about two and one-half miles. The grades can be much improved by a new location, which will place it much further up on the river bank. Above this no railways are affected on either side to Des Joachims.

Just below Skead's mills about 200 acres will be flooded, and at Britannia the low land east of the main street. At Deschenes a portion of the low land will become useless, and above Victoria park, Aylmer, the swampy part of the shore will remain covered; also at Breckenridge bay and at Quio. On the Ontario side the chief flooding will be up Constant creek, the bed of which is a marsh and flooded at ordinary June level, which is, of course, the raised surface of the reach from Aylmer to Chats.

The water supply at Ottawa city has its intake just below the proposed dam. During the construction of the dam, the rock rolling into the river may render the water somewhat muddy, as the end of the dump approaches the part of the river that directly feeds the intake, and the pent-up current rushing past the toe of the dam may affect the intake crib. It seems advisable, before commencing the dam, to construct a new intake above the proposed dam site, then for all time the city will obtain a supply from the deep lake that will be created.

It is possible that a large population of workmen engaged in construction along the river, and living in camps close to its edge, may infect the water to a dangerous extent with typhoid and tuberculosis; therefore, an organized sanitary corps, with police, &c., will be required throughout the river valley.

The construction would require three or four years, depending on the rate of excavation at Hull and at Deschenes rapids.

Time to Navigate.

Lock No. 2	·75	hours,	Hull.
1 mile at 6 m.p.h.	·16	"	river dredged.
30 " at 12 "	2·5	"	Aylmer lake.
1 " at 6 "	·16	"	canal
	3·57	"	

ARNPRIOR REACH.

The Chats locks I have designed as a single lift of 50 feet. Under other circumstances this would necessitate side walls 72 feet in height, but the site chosen—Egan island—affords a rock surface almost as high as the top of the lock. The lock chamber will be carved out of this island and faced with concrete, leaving only 10 feet in height of wall to be actually built. (See plate 43).

The large stresses due to the lock full of water are, therefore, amply provided for by the rock walls, and the question arises, can the lower gates, 72 feet in height, be constructed of sufficient strength? Steel gates are, of course, to be used, and gates of this material, 60 feet in height, are already in use in connection with the Assouan dam, Egypt. At Lockport, the end of the Chicago Drainage canal, wooden gates are in use for a lock of 40 feet lift. The width of this lock, and also the Assouan lock, is small, but at Cascades, Oregon, steel gates for a 24-foot lift and width of 90 feet are in use. By a strange conincidence, the three locks at Cascades, Quebec, have each nearly 24 feet lift, the gates being of solid wood construction, 40 feet high, and the width of the lock 46 feet.

In 1901, Mr. Goldmark designed steel gates for locks up to 40, 48 and 52 feet lifts. His very exhaustive investigation makes it clear that steel gates are quite safe, and of very simple construction and operation for these high lifts. (See plate 32 and 33).

Mr. Goldmark was consulted, and has designed steel gates for this project. He has also designed those to be used on the Panama canal, which are 74 feet high, and for a width of lock of 110 feet. I have, therefore, no hesitation in recommending the adoption of a 50 foot lift lock, although it is unusual. (See Appendix C.)

Below the lock the entrance channel is a mile long, necessitating half a million cubic yards of excavation, three-fourths of which is rock. Above the lock is a canal 1½ miles long through gneiss rock of very irregular surface, averaging 15 feet in depth. (See plate 8).

The course of the canal is intersected by deep ravines, one just above the lock, one at Blind bay, and one at Black bay. It will be necessary to form an outside bank to hold in the canal water, which will be 15 feet higher than the river surface on the other side. The only material at hand is the excavated rock, of which there is a large quantity; three quarter million cubic yards in solid, making 1½ million cubic yards loose. The ravines are, therefore, filled with loose rock, and the side bank is also formed of it. The leakage in the bottom and sides can be staunched with gravel, sand or clay, large quantities of which are near at hand.

At the head of the canal—mile 155½—is placed the dam. This is a rock-fill bank stretching across the river at Lavergne point. The sluices for regulation, stop-log type, are placed on a rock foundation, advantage being taken of two islands near the south shore.

The river is narrow just above the dam site, but fortunately the area is still sufficient to pass the flow at about 3 feet per second. It is possible to increase the outflow by a channel through Lavergne point, emptying below the dam, and an additional outlet, of small capacity however, is furnished by a branch of the Mississippi that flows south of Great Chats island.

Above the entrance to the Chats canal, about one mile of rock dredging is necessary through the shoals and islands that dot the river. This, however, will be in limestone, which overlies the granite at this point.

Between Chats and Arnprior a small amont of dredged channel is necessary, and there is also earth to be dredged nead Blackhead island; otherwise the channel is wide, deep and fairly straight up to the foot of Chenaux lock.

Chats lake is to be held at ordinary high water level, so there is no great damage from flooding, but a considerable area at Norway bay will be rendered useless on the north side, as well as at Black bay and the mouth of the Bonnechére on the south.

The Chats canal excavation—over half a million cubic yards of rock—will require three years to complete and during that time dredging plants would have finished the submarine work.

Time to navigate.

Lock..........................	·75 hours,	Chats.
2 miles at 6 m. p. h.................	·3 "	canal.
17 miles at 10 m. p. h.............	1·7 "	Arnprior lake.
	2·75 "	

Portage du Fort Reach.

This level extends from Chenaux lock—mile 174—to Rocher Fendu lock No. 1—mile 187. (See Plate 9.)

Chenaux lock will make a rise of 35 feet. It is founded in a solid rock island, so that the sides will be almost entirely in solid rock. Below the lock 60,000 cubic yards have to be excavated for an entrance, which can be coffer-dammed off and excavated dry. Above the lock a deep channel is at once entered; in fact it will be necessary to fill two deep holes with loose rock in order to found the upper guide crib at a reasonable depth. (See Plate 43.)

Chenaux is so called because there are four channels, by which the river forces itself through between the rock islands that close the west end of Chats lake. To force itself through, the water is penned up above, creating a swift current, due to a drop from 2 to 3 feet in half a mile. Steamboats can forge their way up this current in summer stages of water, but the channels are narrow, and large boats would be in danger. To widen the channel would necessitate ¼ million cubic yards of rock dredging, and when boats did pass through, they would encounter strong currents all the way to Portage du Fort, and a large outlay would be required to obtain the necessary depth. I have, therefore, selected Chenaux as the site for the lock and dam.

There will be a rock-fill dam across the steamboat channel to the south of the lock, and to the north it will extend across the islands to the head of Elliott island, and then across the north channel where a rock island divides it into two narrow branches. The north shore is a steep rock bank with a flat top. This will form a fine buttress or shore end for the dam, and upon the flat rock top the regulation sluices will be built.

The excavation from the lock pit and lower approach amounts to 170,000 cubic yards, which will double in the loose, making 340,000 cubic yards. Of this 40,000 cubic yards is required for the concrete of the lock, and the remaining 300,000 will be used in the dam. At the regulation sluices it will be necessary to excavate an off-take channel so as to prevent the discharge flowing broadcast and doing damage below. The rock excavation of this off-take and that from the lock pit will make up 500,000 cubic yards loose rock required for the dam, the piers at the lock must be filled with rock from the excavation at or above Portage du Fort.

Above the lock the river surface will be raised 40 feet, the high banks making it easily possible and there will be no excavation up to Portage du Fort—4 miles.

Between mile 179 and mile 180, excavation is required over the top of Ratchford island, Elbow island and Bentley island. The water surface above the village will be raised 20 odd feet, but this will not flood the village itself, except at the lower end and around the shore of Limerick island. (See Plate 9.)

The alignment is fairly good up to two miles above Portage du Fort, where there are two quarter bends in one mile, although the channel is excavated through a small island. There is also some excavation at Old Fort island, where the Calumet flows into the main river. The channel then passes direct into Rocher Fendu lake—

mile 184 to 186. In the lake, which is deep and nearly a mile in width, there is a quarter bend of about one-half mile radius, and between the head of the lake and Rocher Fendu lock No. 1—mile 186 to 187—there is a quarter bend in the opposite direction of a somewhat less radius.

These bends are necessitated by the steep rocky nature of the river, which has given it the very appropriate name of Rocher Fendu, or 'Cleft Rock' channel. It has been said that the Lower Ottawa was an alluvial river, while the upper portion was an archean river, *i.e.*, one flowing through the oldest rocks—granite, gneiss and crystalline limestone, in which the shores are rock bluffs, and the water may be raised to a considerable height without doing damage.

The excavation in this reach consists largely of the removal of the tops of islands down to about the present water level, so that the work can all be done dry, and, as the rock may be wasted in the deep water alongside, the cost of removal should not be high. A tunnel run into some of these pinnacles, and then charged with explosives, should hoist a large part of the material into the river depths alongside without handling.

The total excavation on this reach is over one-half million cubic yards of dry rock, and the time of execution depends upon Chenaux lock-pit, 175,000 cubic yards, which should be excavated in two seasons, and the concrete portion of the walls built in another.

The three tow boats owned by the boom company pass up the Chenaux current a few times each summer. During the construction of the dam the current through the channel will be increased, and these boats will, perforce, be obliged to remain in Chats lake. Saw-logs descending the river during construction will require special handling at each of the dams, but as soon as the locks are built, logs must be rafted, as already stated, and passed through like barges. (See page 109.)

At Portage du Fort there is a highway bridge leading out to Haley's station, on the Canadian Pacific railway. The depth of water is so great that no centre pier is used, and the present span is 300 feet. It can be replaced by a double leaf bascule, giving 200 feet clear channel way.

Time to Navigate.

Lock.	·75 hours,	Chenaux.
3 miles at 10 m.p.h.	·30 "	river.
6 " 9 "	·70 "	river dredged.
2 " 10 "	·20 "	lake.
1 " 9 "	·10 "	river dredged.
	2·05	

ROCHER FENDU REACH.

This level is 35 feet higher than the one below, and extends a distance of two and one-half miles to Rocher Fendu lock No. 2. (See plate 9.)

Lock No. 1 is located on the north side of the river at 'Flat rapids,' where a ledge in the steep canyon side furnishes a site. The rock surface is elev. 285, so that 28 feet of the chamber is in solid rock, leaving 35 feet of the side walls to be built of concrete. The entrance piers above and below the lock are both in prolongation of the north wall, so as to get a foundation along the side hill. The rock is so steep that placing them on the outside would not be practicable. (See plate 44.)

The dam stretches from the lock diagonally across to the point on the opposite side of the canyon. It will be 60 feet in height, and the rock for its construction must be borrowed from quarries on either side, as the lock pit furnishes only enough excavation for the concrete required in its construction.

The regulation sluices will be founded upon the rock point which forms the south shore buttress of the dam. They will be of the stop-log type, and are only required to pass a share of the whole flow, as part of the river will still flow down the Calumet or north channel.

Above lock No. 1 the tops of some islands will require removal—at Barrier and Muskrat rapids. This can be done in the dry, but it does not seem that the excavated rock can be carried down to the dam, as rapids intervene to prevent carriage by scow, and bridges from the islands to the shore would be too costly. The material is, therefore, better wasted in the deep water alongside and borrow pits opened to furnish the rock for the dams.

The alignment through this reach is surprisingly good, owing to the great rise of the water surface, which carries the channel over the top of the islands. Near the dam the water is raised some 50 feet above its present level.

The approach to the foot of Rocher Fendu lock No. 2 is in deep water; in fact only a part of the guide crib can be built immediately below lock No. 2, so the remaining portion is placed upon the islands at Muskrat rapids, about ¼ mile below.

The time for construction would be a couple of seasons.

Time to navigate.

Lock No. 1.	·75 hours,	Rocher Fendu
3 miles at 9 m.p.h.	·40 "	river.
	1·15	

COULONGE REACH.

This level extends fom Rocher Fendu lock No. 2, mile 190—to Paquette lock—mile 209. The June level of Coulonge lake, elev. 350, will be produced down the rock channel of the Rocher Fendu to Lock No. 2, and maintained by a dam in the usual manner. (See plates 9 and 10).

Lock No. 2 is founded on rock, the surface of which is elev. 328, so that 35 feet of the chamber is in solid rock, and 27 feet is the required heigth of the concrete wall. The lift of the lock is the same as No. 1, *i.e.*, 35 feet. The lock site is in a projecting point of the north shore, through which a depression in the rock seems to indicate an ancient pass of the river; in fact the lock and dam will reinstate what was probably once upon a time the river level. Even this raised water level, however, requires considerable excavation, and from the lock to La Passe, 7 miles, there will be one million cubic yards of rock excavation, mostly dry, and one million cubic yards of soft earth dredging. (See plate 44).

The dam proposed is a rock-fill, which closes the depression alongside the lock, and, passing over the higher part of the point, crosses the north channel of the river to Lafontaine island. The island is sufficiently high to form a dam in itself, and it is only necessary to close the south channel of the river at Norman rapid. The dam will require half a million cubic yards of loose rock. Unfortunately, the enormous quantity of rock to be excavated for the channel does not lie conveniently near the proposed dam; the first rock excavation, Desjardins chute, being nearly two miles above, so it will have to be hauled the whole length of French island. Of course this dam, and others too, could be at first made of small proportions, and, when the water was raised, excavated rock from other points could be brought down by scow.

The regulation sluices may be founded upon the high flat rock across the gulley from the lock; the rock surface being just about the proper height. The channel above the lock lies between French island and the north shore.

There is a mile in length of excavation at Desjardins chute, where a couple of islands are directly in the line. Above this a large pond will be formed, in which—

at mile 193—there is a one-eighth bend and some heavy excavation through the point below the old dam and through a projection of Sullivan island above the dam; these two points interlocking as it were across the path. (See plate 9.)

At mile 194½ the rock disappears below grade, and there is 2¾ miles of sand dredging up to La Passe averaging 10 fet in depth. This sand deposit has probably been increased by the building of the dams at Sullivan island, because for 2 miles above La Passe the river is deep. (See Plate 9.)

Between Hennesey island and the south shore, there is a heavy cut in gravel and boulders, and the channel makes a quarter bend in this cut, but at each end there is a deep pond. Again between mile 201¾ and 202½ there is another heavy cut in gravel and boulders. (See Plate 10.)

Here the deep water of Coulonge lake is reached, and the line continues straight up for 4 miles, passing out of the upper end of the lake, between Finlay island and the south shore, through a 7 to 10-foot cutting in clear sand for 2 miles. A quarter bend is then made, in deep water, around Spottswood to the foot of Paquette lock.

The time required to complete this reach will depend upon the rate of excavating 1 million cubic yards of rock between lock No. 2 and La Passe, the bulk of which is near the dam at Sullivan island. The locality permits of rapid work, as the excavation may be disposed of in the deep water above and below, and 3 years may be considered a reasonable time.

The soft earth dredging below La Passe, and also that south of Finlay island, nearly 1 million cubic yards in each case, may be excavated by suction dredge.

The Rocher Fendu channel is very rugged, and has practically been abandoned by the lumbermen. The sides are steep and very rough. The raised water will not cause much damage, but at the head of Calumet island the land is swampy and intersected by Berry river, through which high water now passes.

The raised water will, of course, flow down the Calumet or north channel as well, but will not flood Coulonge Point more than at present. At the Calumet falls below Bryson regulation works will be necessary, and have been provided for.

The alternative route by the Calumet channel has been carefully examined, and is described under the head of alternative routes. (See page 118 and Plate 9A.)

Time to navigate.

Lock No. 2			·75 hours,	Rocher Fendu.
7 miles at	9 m. p. h.		·80 "	river dredged.
2 "	10	"	·20 "	river.
4 "	9	"	·40 "	river dredged.
3 "	10	"	·30 "	Coulonge lake.
2 "	9	"	·20 "	river dredged.
1 "	10	"	·10 "	river.
			2·75	

PEMBROKE REACH.

This level is formed by raising lower Allumette lake to the height of the upper lake. It extends from mile 210 to mile 265, past Pembroke, Petawawa, Fort William (Que.) and through *Deep river,* to Des Joachims. (See plate 11.)

Paquette lock is founded on rock, the surface of which is elevation 350, so that 22 feet of the chamber will be in solid rock, and the walls to be built in concrete will be 25 feet in height, while the lift of the lock is 20 feet. Below the lock is 300,000 cubic yards of excavation, mostly rock, around which a coffer dam may be built and of which 80,000 cubic yards are rock, and there are ½ million cubic yards of rock above, all of which can be excavated dry also. (See Plate 45.)

The dam will be constructed from the rock excavation, and will extend across the foot of Fitzpatrick island and Reid island to Allumette island. Regulation works are provided on Fitzpatrick island. They will be of the ordinary stop-log type with concrete piers founded on rock.

Above the lock the line follows the timber channel between Marcotte island and the Westmeath shore.

The lock and dam are located upon Trenton limestone, and, beneath the surface rock, appears to be chazy shale. During the survey subterranean passages were noted, through which water flowed, and since then it has been found that the rock surface is continually caving in, indicating that new underground channels are forming, and indeed a cave-in has taken place at the proposed lock site. Possibly these caverns could be filled with concrete.

To escape serious difficulty, however, two schemes are open. First to follow the river bed between Fitzpatrick island and the Westmeath shore, and build the lock on an island $1\frac{1}{2}$ miles further up. The quantity of rock excavation would be lessened, but the increased price for excavating under water would render the cost about the same. (See plate 10).

The second alternative route is to branch from Coulonge lake into Hennessey bay, at the head of which a lock and two miles of canal would cross the point to O'Brien bay—mile 212. This line would represent one million cubic yards of dry rock, one million cubic yards of boulder earth, and one milion cubic yards of sand dredging in Hennessey bay, say $500,000 more than the present location of Paquette lock. (See plate 53).

From O'Brien bay the channel leads up Lower Allumette lake, past Westmeath and around the end of Allumette island to Morrison island. The two necessary bends are made in open lake and good water.

At Morrison island the existing Allumette rapid—10 to 14 feet fall—will be drowned out, and a condition similar to that at Deschenes created. The sacrifice of the fall destroys the speed of the current, and the rise of surface above only slightly increases the depth and width of channel, so that excavation is necessary to increase the channel's size and allow a sufficient bulk of water to pass.

There are three principal channels—the main channel north of Morrison island, the Log channel between Morrison island and Moffatt island, and the Lost channel between Moffatt island and Becket island. Unfortunately, neither of the two latter admits of cheap enlargement, as they are both in rock, nor does Haley's bay to the south of these give promise of an easily enlarged outlet. I have, therefore, preferred to make the enlargement in the Allumette rapid itself, by widening the shipway from 300 to 600 feet, giving increased size for boats as well as an increased flow. This entails the removal of $1\frac{1}{4}$ million cubic yards of rock in a bed of chazy shales, which have been before mentioned as wearing away when subjected to the action of water at Paquette island

The excavation may be done dry by beginning work at the northeast point or foot of Morrison island, and finishing to full depth.

The main flow can then pass along Morrison island, and a dam could be built up the middle of the rapid, dividing it in two, so that excavation can be done dry in the channel along the Allumettes shore.

I have placed the price of excavation, however, at $1.50 per cubic yard instead of $1.00 to cover the cost of dams and unwatering.

To the north of Allumette island is the Culbute channel, in which a dam and lock were constructed in 1877. These works will be removed and replaced by stop-log sluices, which, with the ones at Paquette, will govern the Pembroke reach. During construction a considerable flow can be passed by the Culbute, and this will aid by reducing the flow at Morrison island, where the excavation is necessary.

The channel past Pembroke is straight and deep. As the proposed level is only that of ordinary high water, no great damage will be done by flooding, nor will the

water supply or drainage be affected, and it is to be expected that the practice of discharging crude sewage into potable waters will eventually be discontinued entirely.

Four miles above Pembroke, at Leblanc island, the channel passes the Lower Narrows—mile 231—and rock under water must be excavated. Above this for four miles to the Upper Narrows—mile 235—a succession of rock shoals require removel, amounting altogether, with that at the Lower Narrows, to 237,000 cubic yards.

From this to Fort William, Que.—mile 238—there is deep water, and the shoals lying off the chain of islands—Pearl, Oak, Shoal, Gibraltar and Davis—are fortunately avoided without any sharp bends.

At Highview, the channel sweeps around a quarter bend into the famous Deep River stretch, past Oiseau Rock, Schyan Point, Camp Alexander and Fraser's Depot to Des Joachims—mile 265.

The time required for the construction of Pembroke reach is dependant upon the two heavy excavations—over one million cubic yards in each case—at Paquette and Morrison islands. The Paquette work will be straight away dry rock excavation by blasting and steam shovels, and, if four machines are employed it could be done in three seasons. The difficulties in the way of excavation at Morrison island lead me to estimate, that at least four seasons will be required at this place. As all other excavation can be done and the lock completed during this time, four seasons may be taken as the necessary period.

Time to navigate.

Lock No. 1				·75	hours,	Rocher Fendu
(210-212) 2	miles	at 9	m.p.h.	·20	"	river.
10	"	10	"	1·00	"	lake.
1	"	9	"	·10	"	Morrison island.
8	"	10	"	·80	"	lake.
5	"	9	"	·60	"	Lower narrows.
30	"	10	"	3.00	"	river.
				6·45		

DES JOACHIMS REACH.

The Des Joachims rapid is one mile long, and through it the upper river turns squarely north to empty into the side of the '*Deep river*' basin. So sharp is the bend that ascending boats will make a quarter turn in the width of the river in order to enter the lock. (See plate 11.)

The lock is of 40 feet lift, and is located in the bluff rock point opposite the town. The surface of the rock averages elev. 390, so that nearly 40 feet of the chamber is in bed rock, leaving 20 feet in height of walls to be constructed of concrete. The lock-pit itself represents one-quarter million cubic yards of rock, which will be dry excavation, and will furnish enough loose rock for the dam and also the crib-filling above and below. (See plate 45.)

The traffic across the river will be accommodated by a bascule highway bridge over the lock chamber, whence the road will proceed across the river on top of the dam.

Regulation will be provided for by stop-log sluices, similar to those already mentioned, and a solid rock foundation is secured.

Quantities of logs are passed down these rapids every year, and, during the construction of the dam, special arrangements may be necessary till the water rises high enough to allow of their being put through the sluiceways up to the time when the lock is in operation.

Above the lock there is but little excavation, as the water surface is raised 25 feet, but the steep rock canyon sides necessitate a sharp quarter bend and consider-

able rock excavation off the Twin islands, between which the channel must pass. Above this there is fair alignment and great depth of water to Mackey, where the Montreal and Ottawa districts end.

There is an old pass of the river to the north of Des Joachims village, through McConnel lake, by which very high water occasionally passes. This is too rocky and narrow to admit of improvement for large navigation, and a very sharp turn would be necessary to enter the upper end. The raised level of the water surface necessitates a small dam across the valley at the head of this pass, which has been provided for in the estimate.

The time for construction is dependent upon the building of the lock. Two seasons will be required for the excavation of the pit, and another season for the concrete work. During this time the rock excavation off the islands above can be done dry before the surface is raised, so that the time may be set at 3 years.

Continued as Rocher Capitaine Reach on page 127.

ALTERNATIVE LINES, UPPER OTTAWA.

PORTAGE DU FORT REACH (ALTERNATIVE).

At mile 183 the alternative line via Bryson turns east from the chosen line by a quarter bend, and continues on the same water surface, elevation 280, for a mile to Mountain lock. Around the west shore of Hay island rock excavation, 5 feet deep and 150 feet wide, is required, also at Sable rapid and for 800 feet below Mountain lock. This amounts to 40,000 cubic yards of rock and 105,000 cubic yards of earth, which can be taken out dry as the present water surface is just about grade. (See Plate 9A.)

CALUMET REACH (ALTERNATIVE).

Mountain lock is founded on rock, the surface of which averages elevation 265, so that 27 feet of the chamber is in solid rock, and the walls are 35 feet in height.

The lift of the lock is 35 feet, the upper surface being of equal elevation with the middle Rocher Fendu reach, elevation 315.

Above and below the lock are the usual entrance piers, founded on loose rock where the bottom is below grade. (See Plate 52.)

There will be a rock-fill dam from the lock, across the head of Mountain chute, to the high shore on the opposite side. This will require 160,000 cubic yards, of loose rock, which must be obtained from borrow pits as the rock excavation is barely sufficient for the lock concrete and the entrance piers.

Regulation sluices, 20 in number, will be placed on the rock ridge between the lock site and the present timber slide, the rock surface being about the proper elevation for their foundations.

Above the lock the reach will extend for 3 miles to the foot of Bryson lock. There is rock to be excavated at the Dargis rapid and for 1,100 feet below the lock, amounting in all to 115,000 cubic yards, which can be excavated dry.

There are two quick bends in the reach; an eighth bend just above Mountain lock and a quarter bend one mile below Bryson lock. They compare with the two bends below Rocher Fendu lock 1.

Time to complete would be two or three years.

BRYSON-COULONGE REACH (ALTERNATIVE).

The surface of this reach is that of Coulonge lake. Its length from Bryson lock to Paquette is 27 miles. (See plate 9A).

Bryson lock is placed on the island side of Calumet falls, in the line of the old timber slide. The rock surface averages elevation 330, so the side walls are 25 feet high, and the rest of the chamber is sunk into solid rock. The usual entrance piers

above and below are placed along the island side, so as not to obstruct the river flow. (See plate 52).

Below the lock is a narrow section, but the contemplated raise of the water surface from elevation 290 to elevation 315, or 25 feet, greatly increases the channel capacity, and 20,000 c.f.s could be passed with a 3-foot per second speed of current. This will not be necessary, however, as practically the whole river could flow by the other channel at Sullivan island regulation works.

The Bryson dam is placed on the site of the old one, and consists of a continuous line of stop-logs. The flow towards these is square away from the path of vessels, and consequently a cross-current will be created unless most of the flow is passed by the Rocher Fendu channel.

A trial line was investigated from Millar bay to Colton bay, straight across the point separating Portage du Fort from Calumet falls. The cutting for 1½ miles is 60 feet to 100 feet in depth, and the line would cost three million dollars more than the one laid down by the river. The two miles less distance would be counterbalanced by the greater time required to pass through the canal at reduced speed.

At Calumet falls a line through the gully, parallel to the river, proved impracticable.

Above Bryson lock for 5 miles to Campbell bay the channel follows the deepest portion of the river by sweeping curves, which are marked by lights and numerous dolphins or clusters of piles.

The river above Campbell bay is only 400 feet wide between rock sides known as the Grand Rocher, but the depth is 30 feet. From this place, mile 193 to mile 201, the deepest portion of the river is followed with, nevertheless, an average cut of 5 feet, the long swings being marked by lights and dolphins. The excavation from Bryson, mile 188, to Grand Marais, mile 201, amounts to 2,500,000 cubic yards of easily dredged sand and clay.

In Coulonge, the line passes between the principal street of the village and the railway station, necessitating a 200-foot bridge to give access to the latter, and another highway bridge is required at Bryson lock.

The excavation is in soft material to Frost island, and amounts to 750,000 cubic yards. From Frost island to Hennessey island and up to the junction with the Rocher Fendu line, a distance of nearly two miles, the excavation is in hard boulder material, amounting to 300,000 cubic yards.

This route would cost about $1,000,000 less than the Rocher Fendu. It would be three miles longer in distance and one hour longer in time. The whole 16 miles from Bryson is through restricted channel.

As to the danger of silting up with sand, it may be said that modern dredges capable of excavating 20,000 cubic yards per day have rendered this trouble of much less importance than formerly. (See page 102.)

The time required to complete this reach may be set at three seasons, or the same time as for the construction of the Rocher Fendu route. From Chenaux to Paquette via Rocher Fendu, 35 miles, would take six hours. From Chenaux to Paquette via Bryson, 38 miles, would take seven hours.

CULBUTE ROUTE (ALTERNATIVE).

Instead of passing by Westmeath and Pembroke, an alternative route is available by the river channel north of Allumette island. This line leaves the chosen route at mile 208½, just below Paquette rapid, and, instead of turning south, continues directly west past Chapeau to Culbute locks. (See Plate 9A.)

The Coulonge lake level is continued three miles to Waltham lock. This channel below the lock for the first two miles is in alluvial dredging, the north side being always above the water and practically constituting a canal bank. The excavation amounts to about 2,500,000 cubic yards of sand and clay.

The Black river is crossed at mile 201, its surface being the same as that in the canal. No structure would be necessary, but, owing to the silt it carries and the possible cross-current it would create, it has been thought best to divert the river westward, and a new channel ¾ mile long, north of the canal, has been estimated. This will secure the deposit of whatever silt there may be in Lynch lake. (See Plate 9A.)

DEEP RIVER REACH *via* CHAPEAU (ALTERNATIVE).

Waltham lock lifts 20 feet up to the level of Deep river. It is set on rock averaging 350 elevation, so that half the chamber depth is in rock and half consists of concrete walls. The entrance below the lock is in rock. Altogether 100,000 cubic yards will require removal, which can be done dry. Above the lock there is immediately deep water. (See Plate 53).

The dam extends from the head of the lock, forming its entrance pier across to Humphrey island. It will require 250,000 cubic yards of loose rock, which, with 50,000 cubic yards for the lock concrete, can be obtained from the lock excavation and the entrance below.

Another dam will be necessary across the south channel at the Allumette rapids below Pembroke, requiring 500,000 cubic yards of rock and 42 stop-log sluices at Morrison island.

The water surface above Waltham lock will be raised 25 feet, giving more than sufficient depth without any excavation.

The shores are steep enough to allow this rise, and a lake 10 miles long and remarkably straight is impounded, which is from ½ to ¼ mile wide at surface.

The only interruption to navigation is a bridge required at Chapeau about half way up. Near the head, however, at Culbute locks a granite outcrop alters the river to practically a rock canyon for one mile in length.

Rapids existed at this point, but in 1876 a dam and two tandem locks were built of timber by Mr. Perry, C.E., thus creating a slack water navigation from Bryson to Des Joachims, 75 miles. Rail communication, however, was just then extended to Pembroke, and consequently no boat traffic was ever created. The works are going to pieces, but photographs and measurements were made to preserve this interesting example of timber lock construction, probably the largest ever built.

The channel through the rock canyon necessitates the removal of nearly 880,000 cubic yards of rock, which can be done dry by damming the channel just above mile 223. (See page 325.)

Above this the line issues into Allumette lake, and, with only slight excavation between mile 225 and 226, reaches a junction with the Pembroke line near Fort William, Que.

The time to complete this route would be governed by the 800,000 cubic yards of rock excavation at Culbute, which is big blast work, the rock being almost vertical and 72 feet high. One point is 300 feet square and contains 225,000 cubic yards. This could probably be removed in two seasons, during which time the cliffs on each side below it and the large areas at the wooden locks could be disposed of.

From Paquette to Des Joachims via Pembroke, 55 miles, would take 6¾ hours.

From Paquette to Des Joachims via Culbute, 45 miles, would take 5½ hours.

The Culbute route would be about one million dollars cheaper than the Pembroke route, but it is almost certain that a branch from Fort William, Que., to Pembroke would have to be dredged, which would make the two routes cost the same amount. The Pembroke route is wider, giving better facilities for passing.

C. R. COUTLEE.

REPORT BY MR. S. J. CHAPLEAU, M. AM. SOC. C.E. ASSOC., M. CAN. SOC. C.E.—DETAILED DESCRIPTION OF ROUTE AND PROJECT—NIPISSING DISTRICT.

DES JOACHIMS TO GEORGIAN BAY.

OBJECT.

Upon the consideration of reports, plans, estimates, and much collected data relative to former investigations of the French, Mattawa and Ottawa rivers as a canal project, from the Georgian Bay to Montreal, it was seen that the available information they contained was entirely inadequate to the object in hand. Much of it was open to criticism, owing to the scantiness of the data obtained in comparison to the territory covered; there was an almost entire lack of connection between investigated areas where critical changes of profile, in final design, would probably occur; there was an absence of the known limits of any governing flood contour; and also the fact that 14 foot draft and 2,000 tons was the greatest governing feature with one exception. This exception was the estimate made by the Montreal and Georgian Bay Canal Company for a 21-foot channel based upon data obtained previous to 1904, and which necessarily must have been largely of a speculative nature and not at all in keeping with the laying down of such a project, with that degree of intelligence which that project, being a national one, demands.

It was consequently determined that the survey to be undertaken should be so broad in its scope that no doubt would exist as to the value of the final projected location, the distribution and design of the governing structures, and the estimates for the construction thereof.

The initial decision of the executive was to so prosecute the survey as to permit of a canal project being developed that would allow the navigation of the largest lake steamers in the carrying trade. The size of the lake carriers is well defined by the types existing and building on the Great Lakes at the present time. The tendency of the lake carrier construction is to increase beam and length, the draft being fixed; a condition forced by the limit of depth through the submerged, artificial channels of the St. Mary's river, St. Clair river, Lake St. Clair, and the Detroit river. This depth is 22 feet and is likely to prevail, for the reasons following:—

Lake Superior is nominally 22 feet over the Huron level, and the original profile between them, previous to the present channel cut through the Middle Neebish (completed in 1899) showed approximately a fall of 18 feet at St. Mary's rapids, and four feet in the river from the foot of the rapids to Mud lake.

The channel cut through the Middle Neebish had the effect of flattening the river slope between the above points, necessarily increasing the fall between the head and foot of the rapids, thereby increasing the lift of the Soo locks, which forced a shallower depth on their lower sills, and also a shallower depth through the then completed Middle Neebish channel than was anticipated.

This condition, which prevailed when the survey for the Georgian Bay Canal waterways was undertaken, is now designed to be overcome by the development of the new channel cut through the West Neebish—completed this past year—and the construction of a new lock, which is about to be undertaken in the St. Mary's falls canal, and which when completed will allow the passage of 21 feet between Superior and Huron at the lowest stage of the Huron level.

This new channel cut through the West Neebish—joining Hay and Mud lakes—will naturally tend to further flatten the river slope below the St. Mary's rapids, but it is made deep enough to guarantee the above draft.

In consequence of the above it appears that the limit of draft to 21 feet between the Superior and Huron levels has been reached for some time to come. The same arguments may be applied to the improvements of the St. Clair river and lake, and the Detroit river, respecting the Huron and Erie levels.

Unless some abnormal expenditure is made in the immediate future, for the construction of locks at St. Mary's falls other than the new one now projected, and that will permit the passage of a deeper draft and also a further deepening of the above-named channels, the extreme draft of 21 feet must necessarily obtain.

Harbour accommodations of the upper lake ports are all more or less subjected to dredging operations in order to berth the draft now defined by the above channels. Any increase in the depth of these channels means a corresponding increase in the depth of the lake harbours, to obtain which would require an enormous expenditure.

For the above reasons, the depth on the sills and in the reaches of the Georgian Bay Ship Canal project was determined to be 22 feet.

In the determination of the lateral dimensions of the lock chambers it was only necessary to consult the dimension of the largest carriers built and building, and then allow a reasonable margin for an increase in both. This was done, with the result that the locks estimated for will accommodate 650 feet in length, 62 feet beam, and 21 feet draft, there being 22 feet depth of water on the sills, as stated above.

NIPISSING DISTRICT.

Nipissing district extends from the Des Joachims rapids, about 45 miles above the town of Pembroke, on the Ottawa river, to the mouth of the French river on the Georgian bay, a distance of 170 miles of direct distance. It covered originally that part of the above territory east of Lake Nipissing, but subsequently it embraced the investigation of possible routes across Lake Nipissing, together with supplemental details and additional surveys to those already made by this department in 1901, of the French river from Lake Nipissing to the Georgian Bay.

Every alternative route between similar points within the district has received the fullest investigation and no possible location was rejected until it had been proved to be inferior to another—the elements of cost, ease of construction, adaptability to the class of navigation intended, and alignment entering into the consideration. The total length by direct distance of all routes investigated in this district being 241 miles.

During the first week in October, 1904, the survey was organized and the field work immediately commenced. General instructions, prepared by the department, were issued to the engineer in charge of each party, which covered in full the nature of the work to be undertaken. These were supplemented in detail from time to time by the district office as the work progressed to suit the local condition and the value of the immediate location involved.

With the exception of a survey of the Pickerel river and the closing of the Lake Nipissing triangulation all field work was completed by December, 1905; the field parties disbanded, and the principal officers moved to Ottawa where the final reductions and plans were completed.

That part of the district east of Lake Nipissing was first investigated on account of the problem presented by the Summit section. A duplicate loop of very accurate levels was early carried over this part of the district, and a thorough reconnaissance made of every possible economic route with the assistance of all available plans and profiles of previous surveys.

With this information a profile of raised water surfaces between the proposed different pools, or reaches, was struck, when it became possible to determine the

elevation of the highest possible flooded contour over the areas that would be of necessity affected, following the erection of dams and other regulating works that might be projected in the final design. This made it possible also, to confine the work of the different parties within the limits of the affected area.

The same method of preliminary investigation of the French river later determined the nature and extent of the additional surveys necessary to develop that stretch of river up to the required standard.

METHOD.

The extreme roughness of the country and the entire absence of connected points of the developed areas of previous surveys forced the adoption of an almost continuous triangulation net covering the enitre district; this, with the subsidiary triangulation and main closed traverse, supplied the basic net upon which the topography and soundings of developed areas were subsequently hung.

The main triangulation was verified by consecutive base-lines situated at as suitable intervals as the nature of the country would permit.

For the triangulation and main traverse alt-azimuth transits reading to single minutes and thirty seconds were used. In observing the angles the repeating method was followed closing the horizon at each station with 180°.

Individual triangles adjusted only the normal condition that their angular sum equalled 180°.

Starting from a measured base-line the triangulation was developed to include the affected area and closed on a second measured line. Base lines measured by steel tape with spring balance and thermometer, tape length previously determined by comparison with standard for temperature and tension, the line levelled, reduced to the horizontal and correction for the tape error applied.

Comparison of the measured base-line and its length as brought forward through the triangulation gave the error of the running. The greatest discrepancy was 0·4 feet through eight miles of triangulation; least discrepancy was 0·6 fet through 40 miles of triangulation.

The work across Lake Nipissing connecting triangulation of the Summit with that of the French river approaches secondary triangulation. Some of the sights being as great as ten miles, necessitated the use of the heliograph, and great care in observing the angles and in the adjustment of the triangles; the error of this running was 0·5 feet in 20 miles.

Azimuth, established at short intervals by observing on Polaris or some other circumpolar star at elongation, verified the running and at base-line points determined the correction of the connecting triangulation.

In comparison of carried and observed azimuth between consecutive bases, the resulting difference, after correction for convergence of meridians is that due to the algebraic sum of the errors of observation for azimuth and of carrying the azimuth between bases. In each case examined this was so small as to be neglected as an agent of adjustment.

Main traverse was carried by chain and steel tape, the usual methods obtaining and if by stadia, the reductions for distance and elevation were by formula direct, containing last determination of wire interval, wires being fixed.

Customary method of traverse between triangulation stations was to start from a triangulation station, meander for positions required for topography shots and the circuit closed on the next main or subsidiary station, the back azimuth being carried throughout.

Closure of these lines by latitude and departure with co-ordinate difference of the main stations afforded the required check.

Main circuit closed-traverse closed to within 1 in 1200. Shore line stations united topography and hydrography, and continuous cross-river sites served to further connect the work.

In delineating shore contour and general topography unobstructed by underbrush, &c., the stadia method was used. Wires being fixed, the interval was determined for each instrument on measured bases and redetermined from time to time.

Stadia sites for distance and vertical angle served as an argument to compute the true elevation and location of topography shots by use of diagrams constructed from the interval.

Where much underbrush prevailed, topography was obtained by means of hand level, rods and tapes, with angle mirrors or box sextants for direction; 'Y' level lines along the controlling traverse supplying the initial elevation.

Where the shores were very precipitous and confined long stretches of river, either a limiting contour traverse line was run or the slope, if it were a quick one, was estimated from the shore stations, providing that the limit of the proposed raised water surface would have no material effect.

Location of possible structures was closely cross-sectioned by transit and level or closely developed by stadia.

In general, localities were covered so as to enable them to be developed in 2, 5 and 10-foot contours.

HYDROGRAPHY.

The major part of the soundings were made from the ice; boring machines consisting of an auger geared to a hand wheel mounted on a sled and capable of drilling a 4-inch hole through 36 inches of ice, were used for this purpose. The lay-out was defined by the depth being found, reference being made to the elevation of the proposed water level; these lay-outs, defined by connected traverse, were either in squares or parallelograms and varied from 25 to 500 feet each way. Recourse was also had to boat soundings in the summer, and the use of the sweep-bar, definition by transit intersection, float-line or marine sextant.

MATERIAL.

Information as to the nature of the material worked over, independent of a special party organized for that purpose, was carefully obtained by observation and by test-bars at those points over the entire district where excavation was likely to occur. Also nearby location was noted of such material as would prove valuable during construction.

LEVELS.

The datum plane of reference upon which the levels of the Georgian Bay Ship Canal surveys are based is that of mean sea level at New York, being the same as that upon which the sounding planes of reference of all the charts of the Great Lakes are based.

Very accurate engineer's levels were primarily carried over the entire district east of Lake Nipissing, connecting the terminal bench marks of each field party working therein. Benches at the head and foot of each break in the natural water profile were early established and connected to continuously kept sight gauges nearby.

The final elevation of these bench marks to the above datum was later determined by precise levels carried by a special party from Rouse's Point, N.Y., to North Bay, Ont., a complete report of which will be found under 'Precise Levels.'

The above precise level line terminates at North Bay in bench mark 'Chippewa' No. DXLIV, and from this bench mark, with its elevation as determined by the precise line, the French river levels were carried through to the Georgian Bay—the Huron level—by water level transfer and accurate engineer's levels.

Water level transfer across Lake Nipissing, and along permissible reaches of the French River was made by many simultaneous readings of sight gauges, each accu-

rately connected to its adjacent bench mark, and under the most favourable conditions of weather. Accurate engineer's levels in duplicate or more lines, connected these bench marks over the natural changes of the river profile, and where the surface slope of the river would not permit of water level transfer.

All the above engineer's levels, throughout the district, were carried by the Nipissing district staff. Instrument used was a Gurley 22-inch 'Y' level, with 6 sec. vial, reading two specially made target rods, of the United States Coast and Geodetic pattern, to thousandths.

Refined adjustment of the results of the enginer's level lines was not entered into, it being considered sufficient that the limit of error of each running was within $0\cdot02\sqrt{\text{(miles between B.M.s.)}}$, as it was in each case.

It may be noted here, although the same information will be found in detail in the report under 'Precise Levels' that the value of the 'Precise Level' determination of the North Bay terminal bench mark, and the district engineer's elevation of the French river terminal bench mark, as established by the French river running, were checked by the Nipissing district office, as follows:—

Automatic gauges were established at French river, Collingwood and Toronto, the zero of each tied to an adjacent permanent bench mark; that at French river to the terminal of the French river running from North Bay and those at Collingwood and at Toronto to terminal bench marks of a precise line subsequently run between those points by the precise level party.

The records of these automatic gauges compared with those of the United States lake survey on Lakes Huron and Ontario, over two consecutive seasons, determined by water level transfer, the elevation of the above gauge terminal bench marks independently of their elevations as determined by the precise lines and the engineer's levels from North Bay to French river; thus affording the required check.

All levels other than the above carried by the parties working in the Nipissing district for the supply of the topographic and sounding base, or in defining the surface profiles and elevations of and between the different pools, were run by 'Y' and Dumpy levels with sight rods of the ordinary pattern.

Correction was insured by at least duplicate lines with a set limit of error of $0\cdot08\sqrt{\text{(miles between B.M.s.)}}$

In the survey of the Pickerel river, made subsequent to December, 1905—June, July, 1906, a different method was adopted, of which it may be well to give a short synopsis here.

Haste being essential, time for triangulation could not be afforded and a chained traverse was impossible.

A very accurately carried stadia traverse, starting from and closing on the points of the main triangulation of the French river, which had already been made to the north of the Pickerel river, formed the base. The traverse followed one shore or the other, cutting in points on the other side. This was made by a Heller & Brightly transit reading to 30 seconds horizontal, single minutes vertical, and two special double target, 12-foot rods with vernier reading to 1 one-thousandths. Wire interval determined frequently and reduction of readings for distance by formula direct to interval found; the angles repeated normal and reversed and the instrument maintained in perfect adjustment. Rod readings were the mean of several observations, and rods alternately B.S. and F.S., the target clamped after last reading and checked at instrument. The longest closed traverse was 46·5 miles and checked to 13·2 feet in latitude, and 21·3 feet in departure, the angular error of closure being less than one minute. Another length of circuit of 38·2 miles closed to 29·4 feet latitude, and 5·0 feet departure, the angular error of closure being 46 seconds. Other closed traverses showed the same degree of accuracy. Total traverse was 108 miles direct distance. This was probably as accurate as any stadia work done on this continent, and as less men were required to carry it, proves that a high

class stadia traverse through rough country is less expensive and more accurate than that carried by chain or tape, and compares favorably in results with triangulation where the triangles are small.

Topography and shore-line by two stadia parties followed main traverse and developed area possibly affected by construction that permitted plotting to a scale of 1/4800 within a limit of error of 2 in one hundred; contour interval 5 and 10 feet. Elevations for soundings and topography from B.M.'s of engineer's level line previously run between precise levels terminal B. M. at North Bay and the water level transfer terminal B.M. at French River village.

Limit of hydrography, between grade contours, was determined by channel sweep 200 feet wide of submerged wire, with extremities of sweep fixed by marine sextants to shore stations at short intervals.

Points above grade found by sweep were developed later by soundings with float-line and transit.

PLANS.

Sufficient field plotting was carried on during the progress of the work for the purpose of checking the closures and for the assurance that all the required area to be developed was fully covered. The final plans were developed in Ottawa by the district staff, the main plans being plotted to a scale of 400 feet to the inch. The triangulations and main traverses plotted between their bases by adjusted latitudes and departures without reference to Geodetic position beyond the definition of true meridian at the base line and other prominent points.

Traverse and topography being plotted on this net allowed the contours to be developed on 5 and 10 feet intervals within the range of the work. Upon this the final horizontal location was projected and the centre line profile plotted to a scale 400 feet horizontal and 20 feet vertical. The elevation of grades and raised water surfaces of the different reaches having been previously established in the field, allowed the vertical projection of the location to be made. The above established the limit of the grade contours which allowed cross-sections to be developed over affected areas from which the estimates were obtained.

Locations which would probably be occupied by the controlling structures were plotted separately to scales of 100 feet and 50 feet to the inch, allowing the projection upon them of the proposed works, and permitting cross-sections to be taken off more closely at these places than that required for the channel excavation, &c.

The areas of cross-sections in excavation or embankment required for quantities were taken off by planimeter and the volumes obtained by method of mean distance.

Materials determined by borings both by the district field staff and by the special party organized for that purpose, were plotted in vertical section to a requisite scale on the main sheets, near by the locality where they occur.

BORINGS.

Early in the survey of the Georgian Bay Ship canal, it was seen that the field parties would be unable to investigate fully the nature of the material through which the canal was designed to pass. Individual parties, therefore, were organized for this work under the direction of engineers in charge and operated throughout the district with 'Pierce' boring machines and by means of test-pits dug by hand labour.

Where excavation was shown to occur from the profile in submerged channel or canal cutting, but more particularly at the location where controlling structures were proposed, plans of these locations were prepared for the guidance of these parties, showing thereon triangulation stations and traverse points to enable the borings taken to be plotted correctly upon the final sheets.

The boring party covered the district from Des Joachims to Lake Nipissing, over every route investigated, and also the location of the dam sites and the projected location of the feeder canal.

Borings by this party were not undertaken down the French river below the Chaudiere, as solid rock is in evidence there continually. A detailed report covering these borings will be found elsewhere.

DESCRIPTION BY REACHES.

The Nipissing district begins about four miles above the Des Joachims rapid, or 271 miles from the Custom-house at Montreal, and follows the Ottawa river to Mattawa.

The surface elevation of this part of the river is subject to considerable variation during the year, owing to spring floods and the low water of each succeeding fall, some pools having a variation of 16 feet. In order to determine a continuous profile of the water surface over this stretch of river, mileage 271 to Mattawa, gauges placed above and below each break in the river profile were read simultaneously on October 15, 1905, at which time the river was close to its lowest stage. This allowed the proposed changes to be referred to a uniform condition of the river.

The stretch of the Ottawa river which lies between the Rocher Capitaine and the Des Joachims rapids stands at about elev. 388, is 18½ miles long, comparatively straight, and of considerable depth, excepting at three places where small rapids occur. It is proposed to raise this reach to elev. 410, which will obliterate the rapids and minimize excavation.

ROCHER CAPITAINE REACH.

The rise of the river from Ferris point, mileage 271, to the foot of the Rocher Capitaine rapid is 7 feet. Reilly's rapids, at mileage 278, just above Rockliffe, has a fall of about 2 feet, McSorley's rapid two miles above has a fall of about 3 feet, and the Maribeau rapids just below the Rocher Capitaine have a fall of about 2 feet. The pools between are practically level, with little current except at the mouth of the Dumoine river, which empties into the Ottawa on the north at mileage 275, where a current occurs due to a two-tenths head at the junction.

The river between these rapids is comparatively deep and flows between very high and steep banks, which will permit it to be raised to elevation 410, or about 20 feet at the head of the Des Joachims rapid, and 13 feet at the foot of the Rocher Capitaine rapid without causing undue damage. This is obtained by dams near the foot of the Des Joachims rapids where will also be situated the regulation sluices for the control of the reach to the Rocher Capitaine above.

The raised level would back up Mackey creek west of French's lake to beyond the line of the Canadian Pacific railway, which crosses the creek about 2 miles from its mouth. No damage would occur to the roadbed other than what could be remedied by about 500 feet of rip-rap on either side of the crossing.

The Pembroke road would require to be diverted some distance south in order to obtain a good crossing.

Raising the present surface of the river to elevation 410, will drown out the 3 rapids below the Rocher Capitaine, and only a small amount of excavation will be required to obtain a channel width of 300 feet, and 22 feet depth at those points. The excavation is considerably scattered at each locality, while between the rapids the river is wide enough to meet the required conditions.

The centre line as laid down shows several changes of direction, the sharpest of which would approach a 45 minute curve over a length of about ½ mile.

A spur from the hills, which confine the river on the north, turns abruptly to the south at mileage 285, throwing a rock and drift barrier across the river at this point; this causes the Rocher Capitaine rapids, which have a fall of 40 feet in about 1½ miles, and the natural course of the river through them is narrow and very tortuous.

Two propositions were presented here to carry the canal line over this divide:—

One was to throw a dam across the river at the Maribeau rapid to maintain the water above it at elevation 470. This would raise the water level above the Rocher Capitaine rapid by 30 feet, and below by 73 feet, when with a flight of two locks in Maribeau island, on the north shore, the present course of the river could be utilized as a channel, the raised water surface giving a sufficient width. Two sharp quarter bends occur in the channel above the Maribeau rapid, one following the other in the opposite direction, making practically a reverse curve in less than one mile. The Maribeau dam would require to be 95 feet high at its highest point and about 2,600 feet long, with regulating works at one end. The locks would have to be constructed on a very expensive and difficult foundation, to accomplish which enormous coffer-dams would be required.

While the above proposition would allow more of the natural channel the river has already cut for itself to be taken advantage of, it was rejected for the other more easily constructed project, that of cutting a channel through the spur of the hills to the north of the rapids, with locks at the lower end, nearly all of which can be constructed in the dry. Dams and regulating works at the head of the rapids will maintain the river level between there and the Deux Rivieres rapid at elevation 470, or 30 feet above its present level.

The 60 feet difference of level between the proposed two pools will be overcome by a flight of 2 locks having a lift of 30 feet each, with sufficient cribwork lining the approaches above and below.

A channel cut 1¾ miles long will join the upper end of these locks with the river above. This will average 18 feet in depth of cut for ⅝ miles, 40 feet in depth for ½ mile, the remainder of the cut being small. The cut will be 250 feet bottom width and contain 2 slight curves. The upper entrance to the lock is on a 2° curve for 1800 feet, and where the channel cut passes to the river at its upper end there is a 45 minute curve for 4,000 feet. The total excavation for channel and lock pit will approximate 2,311,932 cubic yards, 1,232,329 cubic yards of which will be rock. The locks will have rock foundation throughout and ⅝ of their depth is below the original surface of the ground. Part of the lower lock pit, all of the upper and the channel above, will be dry work; a heavy coffer-dam below the lower lock will be necessary.

The locks are designed to be of solid concrete throughout, except the gate abutment quoins which are of granite masonry. They are to be operated by culverts through the side walls at the floor levels and will be controlled by cup-valves, while double sets of steel gates at the upper, intermediate and lower sills will aflord the change of level.

A hydraulic-electric plant situated near the lower end of the lower lock and supplied by water under 60 ft. head from the canal above will furnish the power for operating the lock gates and valves, and for lighting the canal above and the approaches below.

The dams to hold back the upper pool will be of the rock-filled type in the main channel of the river and across the sny at the upper end of the Rocher Capitaine island. Their upper face will have a 3 to 1 slope, with timber mattress and earth filling, the proportion of rock to earth being about 1 to 4. Together they will contain about 177,552 cubic yards. 'Stoney' gate regulating sluices running from the north end of the river dam will govern the level between here and the foot of the Deux Rivieres Rapid. They will close openings 20 feet deep by 40 feet wide between substantial concrete piers and are designed to pass 40 per cent in excess of the maximum

regulated flood discharge. Running from the north end of the regulating sluices to the raised water contour will be a concrete dam having an average height of 20 feet.

The piers between the regulating sluices will carry the operating machinery for the sluices and also a highway bridge which joins the roadway over both dams connecting both shores.

Concrete cut off dams will extend from the entrance walls of the upper lock to the flooded contour; these will be below the filling behind the walls and cribs and are to prevent leakage from above.

The crib work approaches to the lock will have a total length of 3,400 feet. At the upper entrance to the channel cut there will be an entrance crib about 1,000 feet long; this cribwork will average 30 feet in height.

The reach above the Rocher Capitaine, when raised to elevation 470, will prove an excellent channel for navigation to the foot of the Deux Rivieres rapid 10 miles above, and no excavation will be necessary along this reach. The river here will average over 1,000 feet in width; several bends will occur but they are long and of easy curvature; no damages are incurred through raising the water surface in this pool.

DEUX RIVIERES REACH.

Over the Deux Rivieres rapids the river falls 33 feet in 3 miles. The lower rapid, the Deux Rivières, at mileage 296, has a fall of 15 feet in ½ mile; the next above, the Trou, where the Maganasibi river flows into the Ottawa from the north, has a fall of 7 feet in ½ mile; ¾ of a mile above the Trou there is very swift broken water known as the Toro rapid, and immediately above this are the LaVeillee rapids. From the head of the Trou to the head of the LaVeillee, a distance of 1½ miles, the fall is 12 feet. The fall of these rapids, together with the river slopes between them, forms the Deux Rivieres rapids.

From the head of the Deux Rivieres rapids to Mattawa, 19½ miles further up, the river is well contained between steep slopes of high Laurentian hills, and for the first nine miles above is in a fit condition at the present time for the required scale of navigation. Between Klock, 9½ miles above Deux Rivieres, and Mattawa, 10 miles further up, there are two small rapids—the Rocky Farm, immediately above Klock, 2 miles long with a fall of 4 feet, and Burritt's ¾ miles long with a fall of 4 feet. These rapids are quite shallow and the current through them is about 4 miles per hour.

The river at Mattawa stands at about elevation 486.50 and at the head of the LaVeillee rapid at 475, making a total fall of about 12 feet between the two points at low water. At high water the fall is greater owing to the river expanding below.

By raising the river at Deux Rivières rapids to elevation 500, 30 feet above the pool below, navigation may be obtained through to the town of Mattawa, where the route must necessarily leave the confines of the Ottawa river, and where the next step in the canal profile will occur.

Two routes were investigated to overcome the change of level necessary at Deux Rivieres.

In the first route, the canal line follows the river, the lock being placed at the foot of the Deux Rivieres rapid close in to the south shore, the dam containing the regulating works thrown across the river to the north.

In the second or adopted route, the canal line enters the south shore below the Deux Rivieres rapid where a lock gives the requisite connection between the two pools. The dam will be thrown across the river about in line with the lower gates and will be of the rock-filled type similar to the Rocher Capitaine dam. It will be about 800 feet long, 75 feet high at its middle point, and contain about 306,259 cubic yards. The regulating sluices to maintain the upper level at elevation 500 will be between the foot of the lock and the dam.

The regulation will be by 'Stoney' gates against openings 30 feet deep by 40 feet wide, and designed to pass, when wide open, about 40 per cent in excess of the

maximum regulated flood discharge. These gates will be operated between concrete piers with concrete abutments keyed into dam at one end and connected with lock at the other; an operating bridge running over all. The apron below the regulating sluices will require to be heavily paved, as the discharge here will necessarily be of a high velocity. The lower entrance crib on the north side of the lock will extend for a distance below the lock to deflect the current from the sluices and sufficient to ensure the easy passage of vessels to and from the lock below; this approach will require heavy stone filling behind it.

The lock will have a lift of 30 feet, operated by culverts under the floor controlled either by 'Butterfly' or 'roller bearing' valves, and double sets of steel gates in the chambers at both ends.

The lock, regulating sluices, and dam, will rest upon a rock foundation. The main coping of the lock wall will be about 20 feet above the present surface of the ground which slopes towards the river on the right about 1 in 20.

Above the lock, a canal 250 feet wide, and a little more than 1½ miles long, with an embankment on the river side, leads to the basin above. This cutting will average 17 feet in depth and will contain (including lock pit) about 1,153,041 cubic yards. The excavated material will be used for the embankment which reaches from the upper entrance of this canal to the north entrance crib of the lock, 1,000 feet of which, at its lower end, will have a puddle core.

The main dam will produce a very large basin of water immediately above it, a large part of which will flood the land through which the canal must necessarily pass. The embankment on the river side of the canal, for which there is ample material in the excavation, will allow slack water navigation through the canal, undisturbed by cross currents that would be set up by the regulating sluices at the lower end passing such a large amount of water.

The north chamber wall of the lock during operation, takes on the nature of a concrete dam between upper and lower quoins. It is heavily built with the river side protected by a rock fill, the face of which will have a 1 to 1 stone pitching laid in cement. A concrete core wall from the upper entrance of the lock on the south side to the limit of flooded area is necessary to prevent leakage on this side.

Fifteen hundred feet of cribwork at the lower entrance, and 2,000 feet at the upper entrance of the lock, form the approaches, and will approximate 25 feet in height. Three hundred feet of cribwork at the upper entrance to the canal on the north side will complete the necessary structures at this point.

Power to operate the lock and light the approaches, and the canal above, will be derived from a hydraulic-electric plant situated below the lock on the south side; the water being supplied from the impounded basin under a head of 30 feet.

The numerous borings which were taken throughout this locality fail to show rock except in the vicinity where the lock, sluices, and the dam are proposed. The material elsewhere shows sand, gravel, and boulder drift, the sand and gravel increasing in fineness with the depth. It will be seen, from the diagrams of the borings on the main plans, that fine sand and gravel overlay the rock throughout this section. The material above is a compactly cemented boulder drift, the size of the boulders increasing towards the surface where they are commonly found,. thickly strewn, in sizes of 5 cubic yards.

Above the lock and canal in the reach above, a small amount of channel excavation, scattered through the Burritts', Klock and Rocky Farm rapids and amounting in all to about 83,400 cubic yards will be necessary to obtain the required bottom width of 300 feet. The rapids themselves will be obliterated by the raised water and the channel through them will be entirely submerged; it being defined by a number of pier cribs on either side.

The raised water will necessitate a new location for the main line of the Canadian Pacific railway from Deux Rivieres station, or a short distance east of it, to a point at or about Klock station, in all a distance of about 6½ miles. It was considered safer

to estimate a relocation rather than to estimate for filling, bridging, and stone riprap necessary to maintain the present location between the above points.

In the vicinity of Deux Rivieres the raised water will flood considerable area. The low marshes at the mouth of the Maganasibi river will be covered on the north side of the Ottawa. On the south, or the village side, a large area will also be flooded, the contour of raised water running through the village of Deux Rivieres, crossing the Deux Rivieres creek about 1 mile from its mouth, continuing parallel to the Canadian Pacific railway track for ¾ mile, when it turns and runs parallel to the Ottawa river, being deflected from going further east by the Bisset range of hills. Property damaged at Deux Rivieres will have a small value.

This reach contains few bends, none of them being greater than on a curve of 1 degree.

RIVER SLOPE BELOW MATTAWA.

From the head of the Des Joachims to the foot of Rocher Capitaine, and from the head of Rocher Capitaine to the foot of Deux Rivieres the river slopes are very flat, being practically indeterminate at the ordinary stage of the river level, and the rate of flow is very slow except where the rapids are formed by the submerged weirs of the river bed in the former reach.

When these two pools are raised to elevations 410 and 470 respectively, the average area of water section of each will be increased by about 30 per cent, and the average rate of flow will be considerably smaller than at present. Slack water navigation will obtain throughout these reaches allowing a uniform grade in each.

The fall of the river from Mattawa to the head of the Deux Rivieres rapids at high water is about 15 feet in 19½ miles, the principal changes in elevation taking place between the 5th. and 12th. mile below Mattawa, or that part of the river where occur the Burritts', Rocky Farm, and the Klock rapids.

With a view to ascertaining what river slope, if any, might prevail in this reach, when the water surface is raised to elevation 500, calculations were made from 7 sections, each at a controlling point in the river. It was found that, with the raised water standing at elevation 500 at the head gates of the Deux Rivières lock, the water level would probably stand at 501.83 at the foot of the Mattawa lock, with the estimated discharge taken at 45,000 cubic feet per second, which will probably approach the regulated run off at this level during an average year.

With an increased rate of discharge to 60,000 cubic feet per second, which would probably occur in May or June following very high precipitation, this slope would only be slightly increased.

The calculated velocity for this discharge would average less than 0.6 feet per second, except at one or two places where the side slopes confine the river within narrow limits, where the velocity would approach 2.1 feet per second.

Slack water may be, therefore, said to prevail at all stages of the controlled discharge, and to suit which condition the lower sill of the Mattawa lock will stand at the same elevation as that of the upper sill of the Deux Rivieres lock.

In order, however, to be prepared for a somewhat higher water level at the lower end of the Mattawa lock due to extraordinary floods from the upper Ottawa, which will be somewhat checked in their passage through the narrower channels above Klock, the lower entrance walls, and the lower approaches to this lock are given an additional height of 4 feet over that of the other similar locks.

MATTAWA REACH.

We are now at the town of Mattawa, where the Mattawa river flows into the Ottawa river, 319 miles above the Custom House at Montreal. The canal line here leaves the confines of the Ottawa river, passes into the valley of the Mattawa

river and continues in it through the summit lakes which are its source, penetrates the divide separating them from Lake Nipissng, and passes on into that lake.

Two miles above the town of Mattawa is the lower end of Plain Chant lake, a body of water 5½ miles long, very deep, lying between two ranges of hills whose banks are very precipitous and which is of sufficient width at any part at the present time for all canal purposes. The normal level of this lake stands at elevation 517, or about 20 feet above the level of the Ottawa river at the foot of Johnston's rapids, below the town of Mattawa.

Much consideration was given in regard to the most economical line and profile to prevail between the Ottawa river and Lake Plain Chant, keeping in mind the highest elevation to which that lake could be raised, to give the widest channel at the narrows occurring at its upper end, and without imposing too high a lift on the lock connecting it with the lower pool, or too great a height of the controlling dams. Lake Plain Chant itself is well contained within very high surrounding hills, and its present surface could be raised to any elevation that might be projected. These hills recede from the river from the lower end of the lake to the town of Mattawa to such an extent that it would be impossible to carry a Plain Chant level as far down as Mattawa without entailing works of an abnormal character. To extend the Ottawa level by canal above to the foot of Lake Plain Chant would require excessive and deep excavation for 2½ miles through subaqueous boulder drift with a 40 foot lift lock at the upper end, whose entire foundation would have to be enclosed within a coffer-dam. It would seem, therefore, that a single lock between these two levels would be impracticable. A lock at Mattawa and one at the foot of Lake Plain Chant with a regulated reach between was therefore the plan adopted.

The adopted line leaves the Ottawa river at the foot of Johnson's rapid and passes along a natural depression behind the town of Mattawa into the Mattawa river, ½ mile above its mouth. The lock situated just inshore from the Ottawa river will have a lift of 10 feet, the level immediately above standing at elevation 510 or about 10 feet above its present surface. It will be of concrete throughout, similar in operation to that of the Deux Rivieres lock and contained entirely within the cutting. The ground surface along the lock is partly above and very little below the elevation of the coping, allowing these works to be constructed without the use of an entirely surrounding dam. The foundation will most probably have to go some distance to rock, as borings over the lock site showed firmly cemented material of gravel and boulders, but none of the bore holes were able to make grade, about 35 feet below surface. Where bore holes in this vicinity have penetrated to rock, it is generally found that the material overlying the rock is very fine sand followed by a sandy clay and then by gravel and boulders, the boulders being larger as the surface is approached.

For a short distance below and for about 2,400 feet above the lock, considerable cutting will be required. The total amount of excavation between the rivers including the lock pit will be about 1,257,240 cubic yards, the material all being boulder drift.

The approaches to the lock are lined with the usual cribwork, there being 1,600 feet below and 2,400 feet above, the latter widening to a canal of 300 feet bottom width. At 550 feet above the lock the canal will pass under the Kippewa branch of the Canadian Pacific railway. The present grade or alignment of the railway will not have to be disturbed; the crossing being effected by a single track, single span, Bascule bridge, 160 feet between abutments.

The lock itself lies diagonally across what is known as the Pembroke and Mattawa road which will cross the canal by a single leaf Bascule bridge spanning the lock walls above the upper gates.

To maintain the upper level in the Mattawa river above the lock at elevation 510, a solid concrete dam will be thrown across the Mattawa river about 2,000 feet

from its mouth. It will be a little over 1,200 feet long and will average about eight feet in height throughout. This dam will be of the overflow type, the crest standing at elevation 510, affords the necessary regulation to the level above.

Some excavation will be required to obtain grade in the river part of this reach. The amount is small, occurring at different places, and excepting a few rocky islands at the upper end, just below the next lock above, the material excavated will be principally mud. In this reach there occurs only one bend which is a little over ½ mile long with curvature of one degree. With the elevation of the reach standing at 510, the channel through it will be submerged, its bottom width of 300 feet being defined by piers of cribwork at sufficient intervals.

Boom creek flows into the Mattawa river from the south about 1 mile above its mouth, but the discharge is inconsiderable.

Damage to property resulting from raised water will be confined to a few dwellings on the south shore between Poplar and Park Sts., Mattawa, and will be small. The right-of-way for the lock and canal will necessitate the purchase of considerable property within the town limits, all of which has been carefully estimated for by a Land Surveyor especially detailed for that purpose.

PLAIN CHANT REACH.

At the head of the Mattawa reach, 1¾ miles above the town, mileage 321, the side hills which surround the Plain Chant Lake above converge, confining the river within narrow limits at the Plain Chant Chute, the outlet of the lake above.

A dam spanning the gorge at this locality, with a lock on the north side of the river, will complete the connection between the Ottawa river and lake Plain Chant of the Mattawa waters.

The lock will be situated in the side hill of the north shore about 100 feet back from the river, the coping standing some 35 feet above the present ground surface. It will be of concrete throughout, with a lift of 30 feet, similar in operation and equipment to the Deux Rivieres lock and with cribwork lining the approaches above and below.

The dam will span the river from the upper end wall of the lock to the south shore, maintaining the reach above at elevation 540, about 23 feet above its present surface. It will be of mass concrete and of the crest overflow type, its length on the crest being sufficient to regulate the upper level.

A concrete cut-off dam will join the north upper wall of the lock with the raised water contour on that side. The concrete in lock and dams will approximate 98,930 cubic yards.

The foundation of this lock will prove difficult of construction and will require to be enclosed within a coffer dam on 3 sides; it will rest upon rock as will also the cut-off dam on the north.

It will prove difficult to find the required foundation to prevent leakage under the regulating dam in the river section, as the borings, as far as they could be made, failed to show other than the boulder drift below the mud of the river bed.

The south shore is very steep at this point, the slope being about 50 degrees, while the north shore rises more slowly; on both slopes rock was found some distance back from the shores.

The whole surface of the locality is strewn with boulders of enormous size, in consequence of which few borings could be completed; those that were obtained, however, showed the same class of material as at Mattawa and at Deux Rivières, which seems to be characteristic of all this district.

At the north end of the river-dam adjoining the lock, a hydro-electric plant under 30 foot head will supply the power necessary to operate this lock and also the Mattawa lock 2 miles below, besides lighting both locks, their approaches and the short reach of the Mattawa river between.

Some excavation to obtain grade will be necessary between the approaches to the lock above and below, and, at about ½ mile above the lock, part of an island will have to be removed to obtain required width; total excavation will be small.

The reach above the Plain Chant lock is 6 miles long, very wide at its lower end and very narrow for about 2 miles at its upper end. It lies between very high hills having steep banks rising abruptly from the water edge, near the upper end approaching the nature of a canyon.

LES EPINES REACH.

At mileage 327, two sets of rapids occur, one immediately above the other, Les Epines and La Rose having a combined fall of about 9 feet. Immediately above the latter rapid the Amable du Fond river, draining a watershed of 433 square miles, empties into the Mattawa from the south.

Above these rapids the river is tortuous and very narrow in many places and contains 4 sets of minor rapids, and at 4½ miles above, at the Paresseux falls, the river turns abruptly to the south at the end of a very narrow gorge between high and rocky walls, where it is known as Deep river.

By creating the next step at Les Epines rapid and raising the pool above to 557 or about 30 feet above its present surface at the mouth of the Amable du Fond river and 25 feet above its present surface at Deep river, the rapids above will be obliterated, overflow will not occur, slack water navigation will obtain and will permit throughout the reach of a sufficient canal width without abnormal excavation.

This will be accomplished by a dam between the La Rose and Les Epines rapids, with a lock and approaches cut through the promontory to the north. Both dam and lock will be of solid concrete on rock and hard-pan foundation. The dam will be of the crest overflow type, having a sufficient length to maintain the pool above at elevation 557. The lock will be operated by floor culverts and similar in every respect to the single locks before described. It will set almost entirely within the ground surface, except at the lower end where the side hill falls away rapidly.

Between the approaches very little excavation will be necessary, particularly between the lower approaches where the entrance cribs will be short on account of the great depth. This will require a line of cribwork on the north shore about ¼ mile below to enable vessels going up to berth, providing the lock is in use at the time.

Above the lock several projecting points on either side of the channel will have to be removed to obtain the required grade and width, their limits being defined by piers and cribwork, some carrying lights. Much of the excavated material at the lock site can be used in the construction of the lock, dam, crib filling and back fill, the excess being wasted nearby. The total excavation for this lock and reach will be 673,555 cubic yards.

The raised water contour above will do no damage; in the vicinity of Moore's lake which lies between the river and the main line of the Canadian Pacific railway, considerable flooding will prevail, the drowned area having little or no value.

This reach is remarkably straight, having but one change of direction, a ⅛ bend on a curvature of two degrees, which occurs at Bouillon lake where the river is very wide.

PARESSEUX REACH.

The problem that now presents itself, that of connecting the head of Les Epines reach with Talon lake above, 3 miles by direct line, proves the most difficult location throughout the district. The range of hills which confine the Mattawa river on the west above the Ottawa river turns abruptly to the east at the Paresseux falls, throwing a rock divide between Deep river below and Talon lake above. This point is as far as it is possible to canalize the Mattawa river above the Ottawa river, or below Talon lake. To follow the natural course of the river above the Paresseux falls to Talon lake is out of the question, considering a canal of the intended magnitude.

By the river two very abrupt turns of 90 degrees, each in opposite directions, occur within 1½ miles above the Paresseux. One turn is confined within narrow limits by high granite walls and the other would require much excavation to obtain sufficient area at grade. The remainder of the river between the Paresseux and Talon lake is likewise restricted.

Moreover, the lift between the proposed levels of the two pools, Deep river and Talon lake, is 120 feet, all of which would have to be overcome within limits too extreme to permit of the river route being considered. These natural difficulties require heroic measures to overcome them.

The problem is solved in its most economical sense by cutting a practically straight canal from the upper bend of Deep river at the foot of the Paresseux falls through the divide to Talon lake, placing therein the necessary locks to overcome the difference of level.

Leaving the Deep river half a mile below the Paresseux falls, the canal enters the side slope of the hills, where a pair of locks in flight of 30 foot lift each will carry the canal up 60 feet, or from elevation 557 to elevation 617. Here a natural basin is taken advantage of to form a pool between the flight just mentioned and another flight of two locks 1¼ miles above, having a similar lift of 60 feet. This will bring the canal to the adopted or raised level of Talon lake, or what will be known as the Summit Level at elevation 677.

From the upper flight to the Talon lake, a canal cut through rock, ranging from 15 to 50 feet in depth, 250 feet wide, and 1¼ miles long, will complete the connection between the Deep river of the Mattawa, and the Summit level.

Both pair of the flight locks above mentioned will be of concrete throughout and rest within walls of solid rock, the floors of both being about ⅔ below the present ground surface.

Both flights of locks will be operated by culverts through the side walls, and with double sets of gates in each chamber similar to those at the Rocher Capitaine flight, will effect the change of level.

Between the lower crib approaches of the lower lock some excavation will be necessary, but there will be none above the upper lock of that flight for half a mile; the raised surface between the two flights giving sufficient width and depth.

The upper end wall of the lower flight on the east side will extend about 100 feet, turning to the east at that point and continuing about 80 feet, where it joins the side hill to withold the raised water in the basin on that side. On the west side a solid concrete dam will join the lock with the flooded contour.

The material excavated here will be used for concrete in the locks, dams, backing for filling the cribwork, end walls, &c. The amount of excavation will be about 279,271 cubic yards of all classes and the amount of concrete required will be about 172,368 cubic yards.

In the basin between the two locks, and for a length of ⅝ miles below the upper flight, heavy rock excavation will be required. This will amount to 429,000 cubic yards, and all the material will be wasted on the west side of the prism adjacent to the cutting. This cutting will average 250 feet bottom width by 35 feet deep. The basin will now have the required width for passing vessels; its submerged sides being defined by piers.

Joining the end walls of the upper flight, short concrete dams run to the flooded contour on either side to prevent leakage from the summit above around the lock walls to the basin below. The amount of concrete in the upper flight will approximate that of the lower.

The excavation of all classes (dam excavation excluded) in the upper lock pits, and the canal above into Talon lake will approximate 5,810,685 cubic yards. That part not being used for concrete in the upper flight of locks and dams, and for fil-

ling behind walls, will be wasted on the west side. The total amount of cribwork and approaches to these locks will approximate 7,000 lineal feet. The cribs will average 35 feet in height. Those at the upper end of both locks will be on a rock fill foundation.

The channels between the flights and above the upper flight are not entirely straight but conform as economically as possible to the existing conditions; the curvature will be easy, that above the upper flight being greatest, ⅓ of a mile long on a curve of 1 degree and 45 minutes.

To the east of the upper flight a series of small lakes which drain the surrounding hills flow into what will be the basin about midway between the flights. This will serve to regulate that basin by means of sluice gates in a small dam which will block a gap in the flooded contour above the upper lock.

Hydraulic-electric power for operating the gates and valves of both flights and for lighting the whole system between Deep river and Talon lake will be developed at the lower flight below the upper walls on the river side. The supply under 60 ft. head will be drawn from the basin immediately above.

EAU CLAIRE OR AMABLE DU FOND ROUTE.

Joining Lake Plain Chant with Talon lake above, another route was closely investigated. This route would leave Plain Chant about its middle, mileage 325, and pass through an outlet containing 3 small lakes situated in a narrow cleft of hills to the south of the main river, thence to Moore's lake, Crooked chute lake at Eau Claire, and through Smith's lake to its western end. From this point a canal 1¾ miles long, crossing Johnson's lake, joins Pimisi lake of the Mattawa river about 2⅓ miles above the Paresseux chute. The line from here would continue through Pimisi lake and follow the Mattawa river to Talon lake.

This route shows larger quantities in the principal items than that of the 'Back Line', the adopted route described above, though less in others. It is 2½ miles longer and would afford more open navigation over its length than is to be found on the adopted line between Les Epines and Talon lake. Notwithstanding this its profile area is greater, and it has one more lock than the adopted route.

The locks along the Amable du Fond line would be more difficult of construction, and upon decidedly inferior foundation than the Mattawa river line, and some of the channels, notably where it passes through the gorge below Talon chute, could not be made suitable for vessels passing without entailing the excavation of enormous quantities of rock. The Amable du Fond line would also require a diversion of the Canadian Pacific railway main line from a point 3¾ miles east of Eau Claire station, to a point 3½ miles west; the diversion would be 7¼ miles in length, and its location would pass to the south of the proposed Amable du Fond canal line.

To make the Amable du Fond line available, the Mattawa river would have to be blocked by a dam at the Little Paresseux falls. It would require to be some 1,700 feet long, over 100 feet high at its middle section, and of concrete throughout, for the reason that it would be necessary to conserve the summit discharge for the use of the locks below. The location of this dam is the narrowest found that could be contained within the hills confining the river above the Paresseux falls.

A comparative estimate between these 2 lines, together with their profiles drawn to a suitable scale, will be found in the estimates. The difference in favor of the adopted route being $1,140,000.

SUMMIT LEVEL.

The canal line above the upper flight of the Paresseux locks enters the summit level which extends from mileage 334 to 357.5 embracing lake Talon, the little Mattawan river, Trout and Turtle lakes, their present surfaces being raised to elevation

677. Talon lake will be raised thereby 41 feet and Trout and Turtle lakes 15 feet above their present levels. This is the line and proposition as finally accepted after every other route and other elevations had been given full consideration. Elevation 677 is the highest to which the summit can be raised without a multiplicity of dams at the west end to hold the water above the divide between lake Nipissing and the Summit lakes.

There are 4 summit lakes, Trout, Turtle, Pine and Talon. Trout lake stands 22 feet over the Nipissing level and empties into Turtle lake which is about one foot lower. Pine lake is 12 feet above Turtle and empties into it at its ower end. Turtle lake drains by the little Mattawan river into Talon lake 24 feet below, whose present level is controlled by a timber dam at the Talon chute.

A description of the routes investigated will be better understood by reference to a small plan accompanying the estimate for the summit lakes.

Four routes, joining Talon lake with Trout and Turtle lakes through as many channels as might be made to join them, were surveyed. The areas covered being confined within the limits of the 677 contour.

One route crosses the lower end of Talon lake, passes into the Kai-bus-kong creek, the outlet of the lake Nasbonsing to the south, continues in it for 4½ miles, then passes to the lower end of Turtle lake by way of 3 small lakes situated in a natural valley between the two.

Another route leaves Talon lake about midway of its length at Spottswood bay, crosses a rocky divide into Pine lake and continues through it, thence by the valley which contains its present outlet into Turtle lake.

The third route continues in Talon lake for three-quarters of its length, turns abruptly to the south at that point, passes into Pine lake through a short but very deep cutting, and on to Turtle lake on the line last described.

The fourth route continues in Talon lake throughout at its upper end, passing into the Little Mattawan river, the natural outlet of the upper waters, and continues therein to Turtle lake. This route was shown to have the advantage with regard to the amount of material in excavation over any of the other routes.

The second Pine lake route having the least excavation of any of the three other routes, would still be 125 per cent in excess of the Little Mattawan river route in making the connection between Talon and Turtle lakes.

The first Pine lake route, and the Kai-bus-kong routes have the advantage in distance by about 4 miles. The cutting, however, would be excessive and the channel confined within narrow limits for the greater part of its length.

The adopted route will allow of lake navigation throughout the whole of Talon lake, and for over 2 miles of the lower part of the Little Mattawan river and for the above reason this line was adopted.

The comparative profiles of the above, drawn to a suitable scale, and showing the centre line areas in excavation will be found in the estimates.

The water will be raised in the summit lakes to the required elevation by a solid concrete dam thrown across the river about half a mile above Talon chute. This dam will be on rock foundation throughout with a length on crest of 1,100 feet and the flow over it will maintain the Summit at elevation 677. The average height throughout the dam will be about 30 feet, the section in the river being about 50 feet high for 60 feet in length; it can be constructed entirely within dry foundation.

When the summit lakes are raised to the proposed level Talon lake will allow 8 miles, and Trout lake 7 miles of free navigation. At the lower end of Trout lake, at many points in Turtle, and throughout the Little Mattawan river from the foot of Turtle to Whitefish lake, considerable excavation will be necessary to obtain the required width of 300 feet in submerged cutting.

Between the latter points rock was found along the side slopes of the confining hills, the borings in the river along the line showing the usual heavy boulder deposit

underlying the mud of the river bed. Some rock, however, is shown in this cutting at the upper end of Wolfe pond.

Excavation in Turtle lake and at the lower end of Trout lake will all be in rock.

At the upper end of Trout lake, mileage 335·5, the canal line leaves the lake and passes through the divide which separates it from Lake Nipissing, 3½ miles southwest; the height of land passing within half a mile of Trout lake. The lock at this end of the Summit is located at the lower end of the rock outcrop which forms the divide, the canal joining it with Trout lake being almost entirely within rock cutting.

This canal leading to the upper entrance to the lock will be 250 feet bottom width and its location takes advantage of several small lakes and the valleys connecting them which drain into Lake Nipissing by the Objibwaysippi creek.

The cut through which the line will pass upon leaving the lake will be very deep at one point, running some 70 feet in depth for about one-eighth of a mile. It will average 40 feet in depth for five-eighths of a mile, and the remainder of the cutting to the lock on the Trout lake side will average about 14 feet. The total amount of rock between Trout lake and the lock is about 1,672,151 cubic yards.

Raising the Summit to 677 will necessitate the closing of 10 gaps in this locality where the flood contour shows where this level would run out to Lake Nipissing. These gaps will be closed by earth dams with puddle cores; eight of them occur along the canal line, above the lock and two others to the south of Dugas bay where the flood level would pass to Rivière des Vases. The dams will vary from 150 to 650 feet in length, but their height is inconsiderable, as they are only 7 to 17 feet high at their middle section above foundation. The material for the construction of these dams is to be found in the immediate vicinity, clay for the puddle cores being found below the lock.

All excavation over the Summit, including lock-pits at each end, can be taken out dry for the following reasons: Talon lake is below elevation 651 the summit grade, which allows a dry excavation in the summit approach to the Paresseux locks. The present channel of the river between Turtle and Whitefish lakes, through which the canal line is designed to pass, can be sufficiently enlarged to drain Turtle and Trout lakes to below the summit grade, allowing dry excavation here and also at many points in Turtle and Trout lakes, and the canal approach to the North Bay lock from above. All this material will be wasted in the immediate vicinity where excavation occurs.

No damage results from raising the summit water to elevation 677.

NORTH BAY LOCK.

The lock controlling this end of the Summit, and known as the North Bay lock, will be almost entirely enclosed within the rock, the elevation of the coping averaging 10 feet above it. It will have the usual cribwork approaches above and below, the material for building the lock and filling the cribs coming from the lock-pit excavation. It will be of concrete throughout, effecting a change of level of 29 feet, and similar in construction and equipment to the single locks before described. A single leaf bascule road bridge across the lower approach walls will afford the necessary highway communication on the North Bay-Bonfield road crossing at this point.

From the foot of the North Bay lock a canal cut 300 feet wide, and a little over 1¼ miles long, will bring the canal line into 22 feet of water in Lake Nipissing. It will average 22 feet in depth of cutting from the lock to Rocky Point on the shore where it enters the lake. The bottom of the lake slopes gradually until grade is reached about ⅜ of a mile out. This cutting will contain approximately 1,740,874 cubic yards, and will be almost entirely of soft material, clay, and sand mixed with clay prevailing. Some rock occurs between the lock and the shore, and on one side of the cut at Rocky Point the percentage of rock to soft material will be about one to ten.

Spanning the canal about 2,000 feet below the lock will be a double track double leaf bascule bridge of 170 foot span, carrying the main line tracks of the Canadian Pacific railway—flanking cribs in the cut protecting the abutments on both sides.

The lower approach to the lock will have 1,600 feet of cribwork on the south side and, flanking the cut on either side, where it extends into the lake, will be lines of cribwork 3,400 feet long. These will average 30 feet in height with heavy filling deposited behind them, and are required not only to define the entrance to the canal from the lake, but also to prevent the shifting sand on the floor of the lake from entering the approach.

A line of cribwork 2,000 feet in length will extend along the north side of the cut about midway of its length, it being presumed that a railway terminal will prevail at this locality, as it is naturally suited for that purpose.

A large amount of the material in this cut could be taken out by dredges and wasted in the lake or deposited through pipes from suction dredges to make up land behind the line of cribwork on the north side of the cut for terminal purposes. It could also be used to form a guide bank on either side of the cut where it is unlined by cribwork, as the raised water of Lake Nipissing will flood all this land as far back as the embankment of the Canadian Pacific railway.

Two other routes were investigated for a canal line between Nipissing and Trout lakes; one by way of the Chippewa creek and the other by way of the Objibwaysippi creek. A description of these routes will be unnecessary, as they are inferior to the adopted line both in location and cost.

To pass out of Lake Nipissing at East Bay and cross the divide via Lake Nasbonsing is out of the question, the waters of the latter lake standing 137 feet over those of Nipissing.

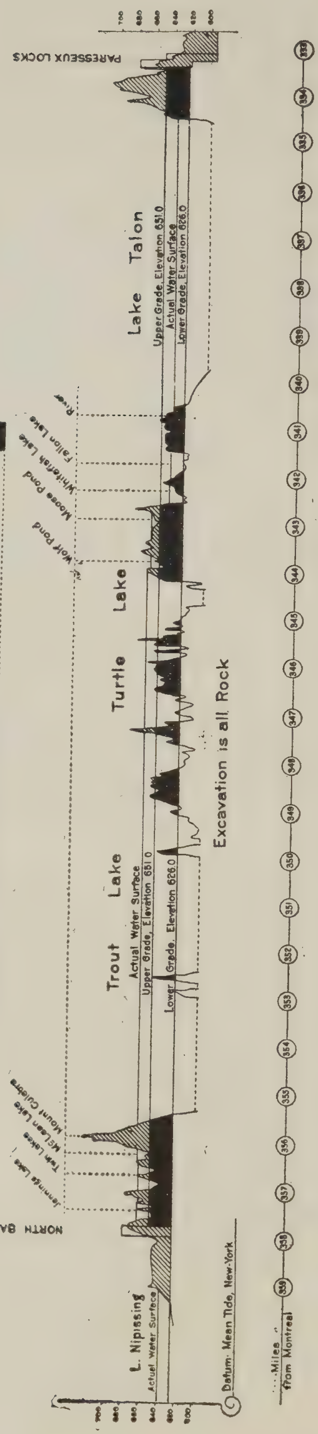
The necessary power for operating the North Bay lock, the highway bridge over its lower walls, the double track bascule railway bridge across the canal below the lock, and for lighting the canal from the entrance piers in Lake Nipissing to its upper end at Trout lake will be obtained from a gas-producer electric plant situated at the lower end of the lock on the south side. Sufficient water to drive a hydraulic-electric power plant is thereby conserved for canal purposes of the Summit level.

LAKE NIPISSING LEVEL AND ADOPTED SUMMIT COMPARED.

An alternative to the adopted grade across the Summit, that of carrying the Lake Nipissing level through to the foot of Talon lake, may be referred to here and a comparison made as to the relative values of each.

An estimate for a canal line 250 feet bottom width down to the Lake Nipissing grade, elevation 626·0 and extending through the summit from the foot of the North Bay lock to what would then be the first lock in the descent of the Mattawa waters—the lower lock of the Upper Paresseux flight—and pursuing the same location as that of the route adopted therein, was carefully taken out and placed in comparison with an extraction from the summit estimates contained within the same points.

These comparative estimates, will be found with the main estimates, where it may be seen that the difference in cost proves to be $8,751,600 in favour of the adopted grade at elevation 651.0, all structures necessary to the latter being included. A comparative profile showing the two grades through the Summit follows:


PROFILE OF
Summit Section showing Comparative Grades
Upper grade shows Summit as adopted, and excavation shown thus
Lower grade shows the Lake Nipissing level carried through the summit and additional excavation shown thus
Excavation is all Rock
PARESSEUX LOCKS
NORTH BAY LOCK
L. Nipissing
Actual Water Surface
Trout Lake
Actual Water Surface
Upper Grade, Elevation 651.0
Lower Grade, Elevation 626.0
Turtle Lake
Lake Talon
Upper Grade, Elevation 651.0
Actual Water Surface
Lower Grade, Elevation 626.0
Wolf Pond
Moose Pond
Whitefish Lake
Fallon Lake
River
Mount Culebra
McLean Lake
Twin Lakes
Jennings Lake
Datum: Mean Tide, New-York
Miles from Montreal
359
358
357
356
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354
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For the purpose of comparison on a basis of similar prices, and in order to make a comparative estimate between the two grades more telling, all excavation in both cases between the above-named points was estimated to be taken out dry.

Accepting the solution of the summit problem as adopted, there is no question as to the possibility of all excavation to grade, elevation 651.0, being taken out dry; the natural barrier which holds back Trout and Turtle lakes, and the Little Mattawan river, can be sufficiently blown out to permit of this being done, and Talon Lake itself can be easily lowered to allow of all excavation in the approach to the upper flight of the Paresseux locks to be similarly made.

To, however, remove the above barriers so low as to permit of carrying the Lake Nipissing grade—25 feet below the adopted grade—through by dry excavation would require the lowering of Trout and Turtle lakes from their present surface elevation, 666.0, to elevation 635.0, or upwards of 40 feet, to accomplish which would be extremely problematical and would certainly incur, at many localities, high prices for submarine excavation in rock, and items for unwatering that would not obtain with the higher grade at elevation, 651.0.

Moreover, the lower grade would increase the amount of material in excavation to a marked degree, as will be seen by a review of the comparative estimates above mentioned.

The main advantages offered by a Lake Nipissing summit level are: No conservation of water necessary, and one level from the outfall at the Chaudiere on the French river to the foot of Talon lake, 68 miles, thereby allowing continuous navigation throughout, or no locking into and out of a higher summit.

The construction disadvantage to obtain this consists entirely in an almost continual cut from about ¼ miles out from the Lake Nipissing shore, through to where would be the first lock in the descent of the Mattawa waters, except in the main bodies of Trout and Talon lakes.

One and a quarter miles at the Nipissing end of this cutting would be through soft material, the remainder being solid rock; the length of the different cuttings will aggregate 11¼ miles. These cut channels vary in length from ⅛ to 3½ miles, and are either contained between high walls of solid rock or in submerged rock cuttings, all being on curves not exceeding 2 degrees.

The navigation disadvantage of such perilously confined channels is obvious and would most probably cause a greater loss of time in transit between the Lake Nipissing and what would be the first lock of the Mattawa waters, than by a Summit as adopted to the higher grade of elevation 651·0, even with the additional time required for lockage at each end.

The cut channels which obtain with the adopted grade aggregate 7 miles in length, 5¾ miles of which are in rock; of the latter 1½ miles are wholly contained within the cutting and 4¼ miles in submerged cutting.

Moreover, with the adopted grade the open stretches of the summit are singularly wide and deep and will allow of full speed over almost its entire length.

With the Nipissing summit the time in transit between the east end of that lake and what would be the first lock of the Mattawa descent would be 4¾ hours, on a basis of 5 and 6 miles per hour through the confined stretches, and 10 miles per hour in the open; with the adopted grade and the same basis and allowing 45 minutes at each lock, the time between the same points would be about four hours.

All of the above argues in favour of the Summit as adopted.

LAKE NIPISSING REACH.

Lake Nipissing and the upper end of the French river form the reach below the North Bay lock; it extends from Rocky Point about 1½ miles below the town of North Bay, mileage, 359 above Montreal, to the first lock on the French river at the Chaudiere falls, mileage, 389. This reach affords free navigation throughout its entire length of 30 miles unobstructed by artificial channels.

The canal line passes to the south ofthe Manitou islands which lie in the middle of Lake Nipissing, some 6 miles from shore, and thence to the entrance of the French river at Frank's bay, some eighteen miles from the canal entrance at Rocky Point.

From Franks' bay the river is followed for 12 miles to where the largest of the natural outlets of the present Nipissing level occurs at the foot of the upper end of Chaudiere island. This island which is 7 miles long by 3 miles wide divides the river at this point into two outlets; to the north of the island 3 small outlets drain the Nipissing level to the basin below and, at the Chaudiere falls at the south of the island, the main outlet of the Lake Nipissing waters passes to the same basin, at the present time some 25 feet below.

Dams thrown across these outlets are designed to raise the Lake Nipissing level to elevation 648, or about 4 feet above its present high stage. This lake has a fluctuation of about 6·7 feet between low and high water and raising the level 4 feet above the latter will cause damage by flooding at different towns situated on the lake shore and to farm lands at the western end of the lake.

The town of North Bay will not be materially affected. The flood contour there follows the shore along the water front and spreads over the low land at the mouth of Chippewa creek which it crosses below the Canadian Pacific railway bridge. From the Chippewa creek to East bay a considerable area will be under water and about two miles of the Canadian Pacific railway track in the vicinity of the Objibwaysippi creek will require to be raised about 4 feet. Cache Bay is north of the Canadian Pacific railway tracks and will not be affected. Some swampy ground on both sides of the town will be flooded, but the flood contour stops at the tracks at both places. The lumber mills on the shore are high and will not be affected. No damage of any material value will occur at Sturgeon Falls or at Beaucage. Some property at Callender and the railroad yards of the lumber companies there will be drowned out. No damage will take place at Wisawasa or at Nipissing village. The raised water would flood some farms in the vicinity of the Veuve river, but they would be of small value. In all probability new wharfs would have to be built at all of the above mentioned towns.

Solid concrete dams would span the three rocky gorges which are the outlets of Lake Nipissing to the north of the Chaudiere island, their crests standing at elevation 650.

Just above the Chaudiere falls, the main outlet of the lake, a set of 3 'Stoney' sluice gates, closing openings of 40 feet in width by 20 feet in depth over the sills between concrete piers and abutments, will afford the regulation of this level and will maintain the surface of this reach at elevation 648. The foundation of all the dams blocking the overflow of the Nipissing level will be in solid rock throughout their lengths.

CHAUDIERE LOCK.

The Chaudiere falls lock will lie along what is now the Chaudiere portage which connects two bays of the river at that point, about 1,400 feet south of the series of rapids in the main river called the Chaudiere falls. It will be in solid granite rock throughout, the walls of the chamber being enclosed for about $\frac{3}{4}$ of their depth below the present surface. It will be constructed entirely of concrete, except the gate quoin masonry, and will be operated by culverts under the floor controlled by Butterfly or 'Coffin' roller bearing valves at either end. Double stes of steel mitre gates at the upper and lower sills will effect the change of level, in all making the lock of the same type as the single locks at the Deux Rivieres, Mattawa, Champlain, Les Epines and North Bay.

Very heavy excavation in solid rock will obtain for $\frac{1}{2}$ mile above the lock and at three points within $1\frac{1}{2}$ miles below where the sides of points and islands will require to be removed to obtain the channel width of 250 feet, the latter including a canal cut

through Keeso's Point some 850 feet in length and averaging about 26 feet depth of cutting.

The excavated material to obtain the required lock and channels from the Nipissing level to that below will be wasted in the immediate vicinity of the individual cuttings, except a part of that portion adjacent to the lock and approaches, which will be used for concrete in the lock and main regulating sluices, filling of cribs and back filling betwen the lock walls and approaches. The total amount of excavation in lock-pit and approaches will approximate 1,889,165 cubic yards.

Upwards of 4,000 feet of cribwork will be required to line the approaches to this lock, the average length of which will be about 18 feet and the foundation will rest upon level floors of rock prepared for that purpose.

The approach to the upper entrance to this lock must necessarily be upon a curve, in order to conform as nearly as possible to the natural advantages offered by the main river at this point.

The immediate approach to the lock will be straight for some 1,000 feet above; east of that the centre line of channel makes a quarter bend on about a 2 degree curve, the bottom width being from 350 to 600 feet. The approach to the lock below and the cut channels leading thereto are, to all purposes, straight.

The centre line of channel of the Nipissing reach from Rocky Point to the Chaudiere presents few changes in direction, the least of which occurs at 1½ miles above the Chaudiere lock, where a quarter bend on a 2 degree curve in a channel over 1,200 feet in width leads to the lock approaches.

Hydro-electric power developed at the lock site will operate the gates and valves of the lock and light the line from one mile above the lock to 1½ miles below.

The reach below the Chaudiere lock is 13½ miles long, extending to the Little Parisian rapids, mileage 403. The upper nine miles of this reach is entirely free from obstruction and offers a very wide and deep channel even at its present level ,with but one exception at Jeune Marie island, mileage 395 where a cut 250 feet wide and 600 feet long would have to be excavated. The depth of this cutting would average 25 feet and the material would be wasted nearby.

Seven miles of this channel is along the foot of the Chaudiere island, and then for 2 miles the river spreads out over a very large area and is again divided into two parts by what is known as Eighteen Mile island. The channel to the north of Eighteen Mile island would be excellent for canal purposes, were it not that at its lower end it runs into very many narrow channels and lakes, through which the canal line would have to be too tortuous to be considered. It would, moreover, necessitate the following of the French river below Dry Pine lake, which is not as well suited for a canal project of this magnitude as the route followed.

FIVE MILE RAPIDS REACH.

The channel to the south of Eighteen Mile island, along which the canal is designed to pass, has a series of rapids at its upper end extending for 4½ miles and known as the Five Mile rapids.

The first of these rapids are the Little and the Big Pine, having falls of 3.8 feet and 5 feet respectively. They are both about ⅛ mile in length and are separated by a pool half a mile long.

About 1 mile below the Big Pine are the Double rapids with a fall of 3.3 feet and ¾ of a mile below is the Big Parisian with a fall of 5 feet in ¼ mile. Below the Big Parisian, mileage 401, the river is level for 2 miles to where the Little Parisian rapid with a fall of 2·5 feet completes the Five Mile rapids reach.

The Restoul river enters this reach from the south, 2½ miles below the Chaudiere lock. Its flow is inconsiderable and was not measured, as it will cause no disturbance at this point.

By putting a lock and dam at the foot of the Five Mile rapids and blocking the channel to the north of Eighteen Mile island, the reach will be raised to elevation 624, about 28 feet above its present level at the foot, and about 11 feet at the head of the rapids. This would drown out the rapids and serve to minimize excavation through this locality which is extremely rough. The river, from the Little Pine rapids to 5 miles below, is broken into very many small channels and follows a very tortuous course due to the broken formation through which the river passes for the above distance. Numerous rocky islands occur and many points on the main shore project out one past the other, forcing the river to its changing course.

To obtain a channel width upon an alignment commensurate with the undertaking many cuttings will be required where the rapids are now. These will be small, except at one point, between mileage 400 and mileage 401, where the cuttings through Owl Point at the Double rapids and through Point Edward about one-half mile above will be considerable. The depth of the cut through Owl Point will average 38 feet and that through Point Edward about 25 feet. The excavation in both will amount to about 75,170 cubic yards and the total excavation from the Little Pine rapids to the Five Mile lock at the Little Parisian rapids will amount to about 1,183,500 cubic yards. All material will be wasted in the vicinity adjacent to the excavation.

It is certain that the greater part of the excavation to obtain the channel in the rapids above the lock can be taken out in the dry. A tight dam can be thrown across the Little Pine rapid at its head and the channel around Commanda island can be blocked below the outflow of Commanda creek. This would force the waters of the French, the Restoul, the Woolsey and the Commanda to pass to the level below by the channel to the north of Eighteen mile island, thus allowing the river below the Little Pine rapids to be drained to the level below the Little Parisian.

The sides of the cuttings will be defined by piers of cribwork at short distances, many of them bearing lights. Many bends occur on the centre line of channel in this reach, the sharpest being a quarter bend in about five-eighth miles or on a curve of 2 degrees. Nearly all are in that part where the rapids are now located.

FIVE MILE RAPIDS LOCK.

Situated in a projecting point at mileage 403, around which the river runs in the Little Parisian rapids, is the site of the Five Mile rapid lock. It will be of concrete throughout and will rest about half within the rock cutting and will be on rock foundation throughout. It is designed similar in type and operation to single locks before described, and will effect a change of level of 24 feet.

Lines of cribwork on either side form the approaches above and below. Those above will rest for some 400 feet upon a rock fill, the present bottom there being about 30 feet below the proposed canal grade.

To the north of the lock, and spanning a gorge, through which runs the upper part of the Little Parisian rapids, will be a rock fill dam, the upper face of which will be staunched by an earth fill on a 3 to 1 slope, a woven timber mattress lying between the rock and the earth. This dam will be about 550 feet long and fifty high for about 100 feet of its middle length and will contain about 30,837 cubic yards, the proportion of rock to earth being about 1 to 4.

Excavation in lock pit and approaches will all be used in material for concrete, crib filling, and foundation for the cribwork above the lock. Part of the material for the dam will require to be borrowed, which can be done on the north side, where the hills rise to a considerable height above the elevation 628, the crest elevation of the dam.

By enlarging a gulley to the south of the lock and placing therein 3 stop-log sluices, regulation of the reach above is partly obtained. This sluice way will be built of concrete, the openings between piers and abutments of 20 feet width and 15 feet

depth being closed by stop-logs operated from a bridge running over all. A similar set of sluices will be embraced in the dam which blocks the channel to the north of Eighteen Mile island and which will complete the regulation of this reach. This latter dam will be about 6 miles below the Little Pine rapids at a point where the river is confined within very narrow limits.

Power for operating the lock and lighting the approaches for some distance above and below will be obtained from a hydro-electric plant located at the foot of the rock-filled dam.

The reach below the Five Mile lock will stand at elevation 600, and is the longest in the Nipissing district, being 37 miles long, from mileage 403 to mileage 441. The river through which it passes affords for the most part comparatively wide channels of great depth between high walls of granite rock.

The main channel of the French river is followed for a distance of 11 miles below the Five Mile lock, at which point a natural waterway is taken advantage of and so improved as to permit of the canal line entering the Pickerel river at the Horseshoe falls, 3½ miles to the south, and which it follows to its confluence with the French river at Ox lake 16 miles below. After passing through Ox lake the line follows the Middle outlet of the French river into the Georgian bay.

Heretofore, projected surveys have carried the route throughout the south branch of the French river to the foot of Dry Pine lake which is the end of the Eighteen Mile island. Below this point the French river flows in a single channel to Ox lake 12·3 miles below, which is merely a widening at the confluence of the three rivers, the Pickerel, the French and the Whanapitae; the latter river draining the country to the north as far as the Sudbury district.

The French river from Dry Pine lake to Ox lake was fully surveyed and its value as a canal route carefully compared with that of the Pickerel river which parallels it some two miles to the south. The result was that the latter was chosen as the more feasible, that is to say, the less expensive and more adaptable as to alignment than the main body of the French river.

In the French river, 2½ miles below the point where the present location turns to connect with the water of the Pickerel river, is the Lost Child bend. Here the river sweeps to the south and again to the west through two turns of more than one-quarter bend each, and in less than one mile of distance. Below these bends the river passes to Dry Pine lake through a very narrow channel between precipitous sides, the width being little better than 200 feet. Dry Pine lake at this point is barely 1,500 feet across and, although very deep, the outlet of it into the continuance of the French river beyond would necessitate two full quarter bends being followed in that distance. The entrance to the river below is barely 200 feet in width and passes between granite cliffs. Throughout the remainder of the river, until it widens into Ox lake, the channel is naturally much restricted at many points, where to secure the necessary width and alignment heavy excavation would occur.

The Pickerel to the south affords for the most part comparatively free navigation, that is to say, upwards of 300 feet channel width from the Horseshoe falls to Ox-lake, and with a comparatively small amount of excavation. The alignment, moreover, is far superior to that which obtains in the main channel of the French, and although some 2½ miles longer was adopted for the above reasons.

At 1 mile and at 1½ miles below the Five Mile rapid lock some excavation will occur to obtain the necessary width of 250 feet and 300 feet, but from this latter point to where the canal line turns to the south, 9½ miles below, the river is wide and deep affording at its present stage no obstruction to the required scale of navigation.

In carrying the canal from the French to the Pickerel river a natural waterway is largely taken advantage of, as before mentioned. This waterway consists of 2 lakes, each about 1 mile long and sufficiently wide along their grade contours to suit the condition.

THE HORSESHOE.

Heavy excavation will be required to enter the upper lake from the French river, to join it with the lower lake, and to pass from the lower lake into Pickerel river at the Horseshoe falls.

The first cutting at mileage 414, will be about 1,400 feet long and 300 feet wide, with an average depth of probably 10 feet. One mile below, parts of 3 points of rock within a distance of 3,000 feet will have to be removed to obtain the required channel between the two lakes, the average depth of cut being about 12 feet. Joining the lower lake with the Pickerel river, a canal cut of about ¾ miles will complete the connection between the French and Pickerel rivers. The total amount of excavation in these cutting will be about 940,790 cubic yards; the material, granite rock, will be wasted nearby where taken out.

Through the Horseshoe cut will exist the most confined section probably along the whole canal location. There the canal line is required to pass through a nearly one quarter bend in ¼ mile, or on a curve of approximately 5 degrees deflection. This bend will take place within a basin having a bottom width of 400 feet, the approach to which, from above and below, will be straight canal cuts of 200 feet width, neither of which will be longer than 1,000 feet.

At the time of the projection of this location it was a question whether boats of the larger lake type could be navigated with confidence through a rock cut channel having the above restrictions. To obtain experienced opinions large size drawings in plan and sections, were prepared of the proposed cut as now adopted, and also a cut of 250 feet width on a continuous curve of 2 degrees and 30 minutes, passing the same locality. Both were submitted to Captain Norcross, the then ranking captain of the Wolvin line of steamers of the upper lakes. His opinion was in favour of the basin with straight approaches, and he had no hesitation in stating that the largest freight carriers would experience no difficulty in passing through this cutting. He recommended, however, that in the event of completion, vessels should not be allowed to cross one another within this cutting, and, as very deep and wide water prevails above and below, this could be arranged without difficulty.

Moreover, three separate estimates were made to pass the channel through this point, that is to say, over the Horseshoe—one on a two degree 30 minute curve 250 feet wide, another the same curve but 200 feet wide, the third as adopted, that is, with the basin and two straight approaches. The latter was shown to possess the advantage of having the least amount of excavation.

The main French river below the Five Mile lock could be lowered probably from 3 to 5 feet by enlarging the section of the Recollet rapids, about two and one-half miles below the Canadian Pacific railway crossing of the French river, and also enlarging the Little outlet at the southwest of Cantin's island, where a small channel from the French river flows into the Pickerel; this would allow much of the excavation immediately below the lock to be taken out dry.

Three small dams, placed across the openings from the French river proper into the upper lakes and the waters leading to the Pickerel river, and with some excavation in the stream at the Horseshoe falls, which at present has a fall of about eight feet, would allow most of the excavation necessary to obtain the crossing between the two rivers to be taken out dry. All channel excavation from the 'Five-Mile' lock to Ox lake will be spoiled adjacent to the cutting.

PICKEREL REACH.

For four miles below the Horseshoe falls the river affords free navigation; in the next mile, however, the river is narrower, between low, rocky shores known as the Cross Narrows. Excavation along the sides will be necessary here to obtain the required width of 250 feet. The sides of these cuttings being submerged, they will

be defined by piers of cribwork carrying lights. At the upper end of the Narrows—mileage 421—the river is crossed by the Toronto-Sudbury branch of the Canadian Pacific railway on a single track, through truss steel bridge of 249 foot span. This would have to be replaced by a double-leaf balcule bridge, the cost of which has been included in the estimates.

The river again affords free navigation for 4 miles below the Cross Narrows except at the 'Flower Pots,' where some points on the north require to be trimmed to obtain a width of 300 feet. All excavation in the Cross Narrows, and at the 'Flower Pots' can be wasted in the main river which is very deep at those points.

Between mileage 426 and mileage 428 some large islands divide the river into 3 different channels, none of which are large enough for canal purposes. The upper end of one of these islands will be cut through to a width of 250 feet and, at 1½ miles below, two points and the Twin islands will have to be removed to 22 feet depth. The sides of the cutting through the island above, and of the Twins below, will be submerged and are arranged to be defined in the manner before described.

The centre line of channel here shows two quarter bends in opposite directions within about 2½ miles, the greatest curvature being 3 degrees. The material in these cuttings will be wasted adjacent to them.

From the Twins to 10 miles below, no excavation will be necessary, the river affording open navigation throughout in its present condition. At mileage 430 the river is crossed by the main line of the Canadian Northern railway, on a single track, deck truss, steel bridge, of 292 foot span. This will have to be replaced by a double leaf bascule bridge, the cost of which has also been included in the estimates.

A survey was carried down the Canoe channel from the foot of Ox lake with a view to locating the canal line within its shores. It proved, however, to be very shallow at its lower end, and not as well suited for that purpose as the line following down the main river to the Middle outlet.

In the last two miles of this reach, where the line turns into the Middle outlet, considerable excavation will be necessary and different points projecting into the river will have to be removed to obtain the required alignment. At half a mile above the lock-site, where are now situated the Dalles rapids, a channel cut of 300 feet wide, and on a slight curve through Tramway Point and Dalles Point, will require to be made. The total excavation in these last two miles will amount to about 220,652 cubic yards. The material excavated from the above-named points will be used in the construction of the lock and other structures below. The submerged sides of the cuttings will be defined in the usual manner by piers.

DALLES LOCK.

At mileage 440, in the main river about 100 feet out from shore, will be located the Dalles lock. This is the final link of the canal chain joining the St. Lawrence river to the waters of Lake Huron.

From the head walls of the Dalles lock solid concrete dams, at right angles to the centre line, continue to the high shores on both sides, and will maintain the level above at this point. Long lines of crib approaches above and below, all in the main river, give ready access to the lock chamber.

The location of this lock is forced by the nature of the country confining the river in this locality. To have placed the lock in the first barrier above the Huron level, the Dalles rapids, might have proved less expensive than the location chosen, but was not adopted, mainly for the reason that the entrances to the lock above and below would then be upon a 2 degree curve of narrow width; moreover, it would entail considerable submarine excavation for half a mile below the Dalles Point which, with the adopted location, will be below grade.

The Dalles lock and the dams spanning the river at its head will rest entirely upon the rocky floor of the river, which here is some 5 to 9 feet below the lower grade,

standing at elevation 556. The lock itself will be unlike the single types designed for the District, as it will be operated by culverts in the side walls controlled by cup valves, and moreover the upper sills will be carried by concrete walls spanning the lock chamber between and below the upper quoins.

Double sets of steel gates above and below will afford a change of level up to 22 feet, depending upon the stage of the Huron level.

When the Lake Huron level stands at elevation 578, or about one foot lower than the lake has been within the records of the last 45 years, there will be 22 feet depth on the lower sills of the Dalles lock.

The lock walls will be of solid concrete throughout, except the gate and abutment quoins which will be cut granite masonry. Filling between the south lock wall and the shore has been estimated for, as access must be had to the lock on that side.

The Dalles lock will be electrically operated, and the approaches to it for 2 miles above and below will be lighted by hydro-electric power developed at the lock.

The reach above the Dalles lock is raised to elevation 600, or about 6 feet above its present surface above the Horseshoe, and 14 feet above its present surface below the Horseshoe. This will be accomplished by 4 dams which will block the outlets of this level which receives the waters of the Pickerel, the French, and the Whanipitae rivers, into Georgian Bay. One of these dams will be thrown across the head of the Eastern outlet close to where it leaves the Pickerel river. Another will block the Bass channel half a mile below where the proposed canal line turns into the Middle Outlet. The third wil block the Middle outlet on either side of the Dalles lock, and the fourth will be situated in the western outlet, or Bad river, about 6½ miles below the Whanipitae lake. These dams are to be all solid concrete, of the crest overflow type, their combined crest length being sufficient for the regulation of this level.

Below the lock the canal continues in the Middle outlet for 2 miles, where the shores of the Georgian Bay are reached. Along this last 2 miles at scattered points, considerable excavation will be required to obtain a channel width of 300 feet. The depth of cutting will be from 1 to 5 feet, and the excavated material will be wasted along side of the cut. A line of cribwork 1,200 feet long on the south side of the cut will mark the entrance to the canal from the lake.

The Georgian bay coast is probably the most dangerous of any on the great lakes, and the entrance of the middle outlet of the French river, while not particularly difficult of navigation, is dangerous, being comparatively narrow, and confined between submerged ledges of rock and small islands.

At the mouth of the French river, 4 miles out from the shore are the Bustard rocks, and safe water in the lake is not reached until 4 miles out beyond these.

It is presumed that, in the event of construction, the most modern definition of this roadway from the lake to the canal will be undertaken by the Deparmtent of Marine, within whose province it falls; no detail estimates, therefore, are provided in this general estimate.

LIGHTS.

The cribs lining the sides of the canal defining the limits of submerged cuttings, and along places where excavation will be made to obtain channel width, are estimated to be not less than 15 ft. x 15 ft x 20 ft. deep, nor more than 25 ft. x 25 ft. x 30 ft. deep, the size of the crib depending upon its location.

Many of these piers will carry lights which will be supported upon them by an iron stand. They are known as the 'Wigam' light, burning kerosene, and are designed for 30 days continuous service.

At many places where straight channels of sufficient length exist, range lights of the same kind afford the required definition; in these cases, however, the lights will be enclosed within lanterns mounted on small lighthouses, the light itself being enclosed by a Hollowfoot lens.

In addition to the ranges, the principal points will be defined by standard lighthouses of the fourth order, each of which would require daily attendance.

The foundation of all the ranges and lighthouses will be of concrete, and their individual cost will depend principally upon the heights of the lanterns above the foundation.

The line across Lake Nipissing would be shown by lighthouses on either shore and at the Manitou islands. These will also be of the fourth order with the extra cost of the keeper's residence near by.

A daily light patrol and a monthly supply service will require to be maintained throughout the season of navigation; the cost of this will be borne under operation, and is estimated elsewhere.

SUMMIT LEVEL.

Previous surveys have seriously questioned the possibility of maintaining a Summit level that would not embrace Lake Nipissing, owing to a belief in the scarcity of the water supply of those lakes which naturally form the summit, and which are taken advantage of in that regard in the present project.

Two reasons present themselves at the present time which undoubtedly caused those opinions: the first being an inability to grasp the topographic value of the basin lying west of the Talon chute, and its possibilities as a storage reservoir when the water level within is raised to its limit; the second, a lack of proper data relating to that watershed, together with a careful study of the conditions as they will exist when the work is completed.

In view of this, it is proper here to discuss the summit generally, that is to say, in all its phases, with the carefully collected hydraulic data in hand, and to set down the conclusions derived therefrom.

The value of a canal system depends upon the relation between its water supply and its necessary drainage through operation and other sources. The present case allows of three conditions, each of which will be considered with reference to that relation. The complete estimates covering each condition have been prepared in detail, and will be found elsewhere.

The water supply of each of the three conditions hereinafter detailed belongs to the report of the hydraulic engineer, and will be found there in detail. It will be sufficient here to compare the amounts of available supply as shown in his report, with the drainage requirements which will be taken as they apply to the summit as adopted.

The three conditions are as follows:—

First, by carrying the Lake Nipissing level through to the Paresseux locks, making a raised summit of Lake Nipissing the summit level.

Second, by raising all the lakes between Lake Nipissing and the Paresseux locks to a common level, thus making a summit above that of Lake Nipissing.

Third, by augmenting the supply of the watershed of the *second* or adopted condition from outside sources.

The *first* establishes the summit level at elevation 648·0, over a distance of 56½ miles, from the Chaudiere falls at the outlet of Lake Nipissing to the Paresseux locks at the foot of Talon lake, and whose supply is derived from the watersheds of Lakes Nipissing, Trout, Turtle, Talon and Nasbonsing, the combined area being 4,420 square miles. These water sheds would together yield a minimum outflow in excess of 4,500 cubic feet per second with control at the present outflow of Lake Nipissing at the Chaudiere falls. This outflow is obviously much beyond the limit

of any canal requirement, so that further discussion of this level with regard to supply is unnecessary.

The *second* is that which applies to the project as laid down and calls for a summit level at elevation 677.0, or 29 feet over the raised Lake Nipissing level, and extending from the small upper lakes or sources of the Ojibwaysippi creek at the west end, to the lower end of Talon lake at the east end, and embracing Trout and Turtle lakes, the Little Mattawan river and Talon lake, a distance of about 24 miles.

This will be accomplished by 10 small puddle core earth-dams at the west end, and a concrete overflow, crest dam just above the present overflow of the Talon chute at the east end. The effect of this will be to raise Talon lake 41·7 feet, and Trout and Turtle lakes 14.3 feet above their present levels, thereby creating a summit basin of 22.4 square miles in area.

This elevation of 677 is the most economic height to raise the water now contained in these lakes, in order to use them as a summit level, from the comparative standpoint of increased height and consequent cost of the lock structures at either end, and the minimizing excavation to obtain grade between them.

By fixing the summit grade at elev. 651·0 a storage of six feet is obtained in the Summit basin over the minimum projected draft of 20 feet on the upper sills of the summit locks.

Lake Nasbonsing, which lies within the same watershed as the Summit lakes, is at present about 148 feet above the level of Talon lake, and will be about 103 feet above the projected summit of 677·0. It flows into Talon lake by the Kaibuskong creek, and with control at its outlet at Bonfield will yield a storage of six feet over its area of 6·54 square miles, and which can be drained to the lower or summit storage level, as required.

The summit is controlled by the fixed elevation of the crest of the Talon chute dam. Any excess of water over the storage level can be wasted into the present river draining these lakes, that is to say, by way of Pimisi lake and the Paresseux falls to Deep river below.

We now have within the summit watershed six feet of storage in Trout, Turtle, Talon and Nasbonsing lakes, over an area of 28·94 square miles, available for canal purposes at the opening of a navigation season. There is sufficient inflow from the watershed from the close of one navigation season (Nov. 24) to the opening of the next (some time in May) to refill them; that is, to make up the amount by which the storage was depleted during the previous season. This is evident from the report of the hydraulic engineer.

Referring to statement No. 4 of that report, it will be seen that the monthly average inflow to the summit basins, between the opening of navigation in May until the middle of June in both years, during which that data was collected from this watershed, is sufficient to meet all demands made upon the Summit for canal purposes, so that there need be no call upon the summit storage during that period for this reason—it will be shown that the total of all sources of drainage for canal purposes will be something less than 500 cubic feet per second, and statement No. 4, above alluded to, shows that during the years 1905-6 the average inflow per day for May and the greater part of June is largely in excess of this amount. The years 1905-6 luckily proved to yield a minimum precipitation and, from comparison with records of the Meterological office, Toronto, over a number of previous years, will safely allow that data to be taken as representing the minimum condition of supply from the watershed.

Commencing, therefore, at sometimes in the latter part of June, the inflow will not be sufficient to supply the demand, and the storage will be called upon to make up the deficiency.

The demand upon the summit for canal purposes is that due to the amount of water required for lockage and all other sources of drainage. By computing the

latter and deducting it from the supply of storage, plus the inflow from the time when the inflow alone becomes insufficient to supply that demand, we obtain the amount of water that will be available for lockage alone, and at once establish the value of the summit.

Upon the amount of water available for lockage depends all speculation with regard to tonnage capacity of canal, for it at once establishes the limit of the interval of time between successive lockages that is possible throughout a season.

Sources of drainage of the summit during the season of navigation other than that of lockage may be classified as follows:—

1. Leakage at lock-gates and valves.
2. Leakage at waste-gates.
3. Leakage at dams.
4. Quantity required for power and light at locks.
5. Loss by evaporation and seepage.

These are the only other sources of drainage for the summit basin and will now be taken up separately and their total determined. Results of computation will be expressed in cubic feet per second.

LEAKAGE OF LOCK-GATES AND VALVES.

General.—This is a question, the data for which must necessarily be assumed, and it is reasonable that some definite assumption regarding that data be made from which to compute the probable loss, and not to asume that volume arbitrarily.

As the levels below the summit are not dependent upon it for supply, and the summit locks are of higher lifts than those of the locks below them, the computation may be confined to the summit locks alone.

The loss through the lock-gates is dependent upon the head against them. As this head is different at both ends of the summit, and moreover as the lock at the west end is a single lock, while that at the east end is part of a flight, they will be treated separately.

The valves for operating the locks are subject, when closed, to the pressure of the entire lift they control, and as they are of a different type in the single lock from that of the flights they will also be treated separately.

UPPER PARESSEUX FLIGHT.

Gates.—The extreme head on the upper gates is 27 feet, and the extreme head on the intermediate gate is 55 feet. A study of the flight profile during the stages of continuous locking will illustrate this.

The head necessarily varies between the above limits during operation, and when the flight is at rest the head depends upon whether a boat has just locked up or down; if the former, the maximum leakage head occurs at the intermediate gate and is that due to a head of 30 feet; if the latter, it occurs at the upper gates and the head is 27 feet.

As the head of 55 feet only occurs during operation, and then only for a short period, it is reasonable to assume that the leakage head would be slightly in excess of the mean of 27 feet and 30 feet; assume it to be 30 feet. Leakage around the quoins, between mitre posts and through lift walls, may be neglected here and accounted for in making up the total for leakage; no reasonable assumption can be made for defects of workmanship in their construction.

Assume that when completed one leaf of the pair of gates will be longer or shorter than the other, and compute the leakage which would follow from this condition. If one gate was shorter than the other, the paid would not miter at the point of the sill, but would do so at some distance above it when under pressure. Framed

steel gates would have sufficient elasticity to allow them to bend inward enough along the axis of the lock to accomplish this, when there would only be a small vertical slot of assumed height and of varying width through which to estimate an amount of leakage.

It would seem more reasonable to assume one leaf of a pair longer than the other, so that when mitered one gate would not close against the sill for its length from miter to quoin. This would give a larger orifice than were the gates a little short, and they would, moreover, seal along the vertical length of the miter post. The dimensions of this orfice may be taken at ¼ inch by 38 feet, or an area of 0·79 square feet under a head of 30 feet, and using the discharge formula for small orfices of $Q=0{\cdot}6 \times ab\sqrt{2gh}$ will give the discharge in this case of 14·7 cubic feet per second.

Valves.—The valves are of the 'Cup' pattern, designed to seat perfectly when closed, both the seat and bottom of valves being machine faced with the vertical movement of the valve being directed by guide flanges. When under head the valves are pressed against the seat by a varying pressure up to 84 tons and there can be no leakage through them.

TROUT LAKE LOCK.

Gates.—The average head against upper and lower gates here would be 28·5, which, under the same assumption as that at the flight, would give 14·4 cubic feet per second loss to the summit.

Valves.—These are either the 'Butterfly' type or the 'Coffin' roller-bearing gate, both having been estimated for. If the latter, the leakage may reasonably be neglected, this type of valve being designed to a machine faced wedged seat all around; but if the former, it may be taken into account.

There would be 4 'Butterfly' valves at each end of the lock, 8 feet square, rectangular, and turning on a central shaft. They would seat on the sides parallel to the shaft, but would require a clearance on the sides carrying the shaft; taking this clearance at ¼ inch and considering 3½ feet on each side of shaft-bearing, would give a leakage for the 4 valves of 21·8 cubic feet per second.

Leakage at Waste Gates.—Above the Upper Paresseux locks a pair of 6 ft. x 6 ft. 'Stoney' gates supply the reach between the Upper and Lower Paresseux flights with the amount drawn from it for power, and may also be used to supply that reach in the event of continued lockage up through the lower flight alone, or for other such emergency. These gates are fitted with water seal rods and are under practically no head, being immediately below the surface. The leakage through them would be small.

Consider that, when these gates are not supplying water for power and are shut, they do not close their sills by ¼ inch; the sill being 10 feet below the surface, the leakage through these orfices would be 2·7 cubic feet per second. When opened to supply the pools between the two flights for power, they could never be regulated exactly to supply that demand, and would probably be opened somewhat in excess. We may consider for this excess and for leakage 6 cubic feet per second. There should be no leakage around the concrete structure as it will be built in the solid rock from foundation to copings.

Leakage at Dams.—There would be 10 dams at the head of Trout lake, from 150 to 650 feet in length and from 7 to 17 feet in height at middle of dam from foundation to water surface. They would have slopes of up and down stream faces of 3 and 2 on 1 respectively, and each contain a 6-foot puddle core, and would be very carefully built, the puddle core cross cut through successive layers, watered and rammed.

There appears to be little comparative data from which to estimate an amount of leakage through these dams. Large openings which would permit much loss would certainly be promptly repaired. The foundations of their ends would be in solid

granite rock containing no fissures; that lying between would be in extremely hard boulder drift and the estimate of leakage through them may be confined to the built-up embankment.

Loss by leakage through canal banks has been estimated in many different cases, the loss being given in cubic feet per mile per minute, based upon the area of the cross-section of the prism. This loss has been taken generally as 'combined loss by evaporation and seepage.' A table showing many measurements and estimates of this loss will be found in the 1901 report of Mr. Emil Keuchling, M. Am. Soc. C. E., engineer for water supply for the New York state barge canal. In this table it is given for 'Canals in general average condition, maximum loss 98·7 cubic feet per mile per minute,' for a water surface width of 52·5, a bottom width of 32·8, and a depth of 6·6. It is to be observed that this leakage occurs through both sides and bottom. If we consider that one bank takes one-half of this total loss, we shall be reasonably safe in making a comparison between it and the dams in question in regard to the leakage through them.

For the purpose of comparison we may rely upon the area of wetted surface in each case, the average depth of water on the dams being about the same as that given in the table. From this table we find that the area of wetted surface of one bank, with a depth of 6·6 and for one mile in length is 63,360 square feet, and the leakage therefrom would be $^{98\cdot7}/_{2}$, say 50 cubic feet per mile per minute. This includes evaporation over a surface 52½ feet wide and one mile long, but we may neglect the evaporation, however, and consider the leakage full 50 cubic feet per mile per minute. The total area of wetted surface of the dams will be approximately 44,800 square feet and the average depth about 6·5 feet, which will give a leakage of 0·6 cubic feet per second through them. This leakage is practically nothing, and might be neglected, but in order to provide for some defects in construction we may assume 4 cubic feet per second loss under this item.

The dam which holds the flooded area of the summit lakes immediately above the 'Talon chute' lies across a narrow gorge and will be of solid concrete on rock foundation throughout. It has no waste gates, the summit regulation being by the crest, which is 1,110 feet in length, standing at elevation 677·0. No leakage need be estimated through this dam. Cut-off dams of mass concrete run from the upper end walls to the contour raised w. s. above the upper and lower Paresseux flights of locks with their copings at the same elevation as the copings of the lock walls. These are of the same nature as the Talon dam with regard to foundation, and no leakage may be expected through them.

QUANTITY REQUIRED FOR POWER AND LIGHT AT LOCKS.

The east end of the summit level is designed to be equipped with hydraulic-electric power station sufficient to operate the gates and valves of the two Paresseux flights, and also light the canal from Talon lake through to Deep river of the Mattawa below the lower entrance to the Paresseux flight An average required for this item throughout the 24 hours would be 13½ cubic feet per second. The derivation of this flow is given in detail in a report of Mr. G. F. Chism, in Appendix S. No water is estimated to be drawn from the summit for power to operate the Trout lake lock, nor for the lighting of the canal from Lake Nipissing through to Trout lake, or to operate the bridges there. A producer gas-electric plant will supply this demand.

LOSS BY EVAPORATION AND SEEPAGE.

The evaporation loss over the summit basins when raised to their proposed elevations is included in the available inflow or natural run off from the water shed, as will be seen in statement No. 4, and tabulated statement No. 5 of the hydraulic

engineer's report. It is therefore accounted for under supply, and need not be further referred to here.

The summit basin lies within high rocky hills through which no seepage could take place after the water surface had been raised for such a time as to percolate the surface soil above the present lake surfaces which would be inundated. Lake Nabonsing has often been held by the present lumberman's dam to the proposed elevation for storage, and any seepage from it would naturally find its way to the summit lakes.

It seems reasonable to venture that, under construction, the workmanship on the locks, gates, and dams in all cases would be of such a class as to preclude the possibility of larger defects than those here assumed. The computed leakage therefrom may be taken to approximate a reasonable limit.

We now have for the summit drainage, other than that required for lockage, the following summary:—

	Cu. ft. per sec.
1. Leakage through lock-gates and valves..	50·9
2. Leakage through waste-gates	6·0
3. Leakage through dams..	4·0
4. Quantity required for power and light	13·5
5. Loss by evaporation and seepage (in supply)..	0·0
Total..	74·4

Allowing for undue leakage around quoins, between miter posts and through lift wall, would bring this total up to, say 80 cubic feet per second.

It will be seen from statement No. 4 of the hydraulic engineer's report that, after June 24, 1905, and June 19, 1906, the inflow from the watershed was insufficient to supply a demand of over 500 cubic feet per second. If the canal had been constructed at that time, and 500 cubic feet per second had been required for total canal purposes (including lockages), it would have been necessary to draw upon the storage after those dates.

By taking a mean of the inflow from June 24 to November 24, in 1905, and from June 19 to November 24, in 1906, and deducting from them the 80 cubic feet per second (the amount required for all sources of summit drainage other than lockage), we will obtain for each of those years the amount of inflow alone that would have been available for lockage. If we add to this the discharge outflow from storage alone in cubic feet per second, between the above dates, we will obtain the total amount in cubic feet per second, that would have been available during each of those two years for lockage purposes alone. This is illustrated by the following:—

The total for 6 foot storage in Trout, Turtle, Talon and Nasbonsing lakes is 4,840,805,960 cubic feet.

1905

Available from storage, June 24 to November 24 = 153 days, 366 cubic feet per sec.

Monthly average from inflow:—

Remainder of June..	196	cub. ft.
July..	155	"
August..	125	"
September..	148	"
October..	244	"
November..	324	"

Season average = 195 c. f. s.

Available for lockage, 366 + 195 — 80 = 481 cubic feet per second.

Available from storage, June 19 to November 24 =158 days. 355 cubic feet per sec.

Monthly average from inflow:—

Remainder of June	280	c. f. s.
July	47	"
August	160	"
September	29	"
October	184	"
November	255	"

Season average = 160 c. f. s.

Available for lockage, 355 + 160 — 80 = 435 cubic feet per second.

QUANTITY REQUIRED FOR LOCKAGE.

The quantity of water required for lockage, in cubic feet per second, over the summit depends upon:—

1st. The amount passed out of the summit per vessel passed.

2nd. The relation of their alternating east and west.

3rd. The time consumed per vessel passing each lock.

The first and second have caused much discussion and misunderstanding, owing to the fact that displacement at first appears to, but really does not, enter into the condition. The following analysis by the late Mr. George Y. Wisner, M. Am. Soc. C. E., is a correct solution of the problem.*

'Let M_1=area of lock × lift, west end of summit,
M_2= " " east "
D_1=displacement of vessel going east,
D_2= " " " west,
Q =quantity of water used,

For vessels locking successively west to east:—
$Q=M_1+D_1+M_2-D_1=M_1+M_2$

For vessels locking successively east to west:—
$Q=M_2+D_2+M_1-D_2=M_2+M_1$

With vessels alternating regularly each way,—for vessels going east:—
$Q=M_1+D_1-D_1=M_1$

For vessels going west:—
$Q=M_2+D_2-D_2=M_2$.

Average quantity used per vessel, $=\frac{M_1+M_2}{2}$

'It is estimated from various canal statistics, that for the entire season, the alternate lockages will average ½ the total number of lockages'—when from the above it will be seen that the average quantity used becomes ¾ (M_1+M_2) or ¾ of the sum of the volumes of the summit locks per vessel passed.

Trout lake lock, (west end) M=1,225,250 cu. ft.

Upper Paresseux, upper lock, (east end) M=1,267,500 cu ft.

¾ (M_1+M_2)=1,869,563 cu. ft. per vessel passed, or 21·63 cu. ft. per second per day per vessel passed.†

We are now in a position to determine the time consumed per vessel passing each lock, or the least interval between successive lockages, that could have taken place

*Trans. Am. Soc. C.E., Vol. XLV., page 331.

†These figures are a maximum, and will decrease as the storage depth of the summit pool (6 feet) decreases.

after the middle of June during 1905-06 under the *second* condition, or that which applies to the project as laid down. The season 1905 would have permitted $481 \div 21 \cdot 63 = 22$ lockages per day, or a minimum interval of 1 hour 5 minutes; 1906 would have permitted 20 lockages per day, or a minimum interval of 1 hour 12 minutes.

The time interval between successive lockages which would probably prevail on the Georgian Bay Ship canal is necessarily a matter of conjecture, but a general idea may be arrived at by comparison of similar locks under similar conditions.

The three locks around the Sault Ste. Marie falls afford this comparison, and the following table compiled from the statistical reports of these locks over several years will serve to illustrate the comparison.

STATISTICS OF SHIP CANALS AT ST. MARY'S FALLS.

Lock.	Year.	Season.	Number of Days.	Total Number of Lockages.	Season Average Number per Day.	Time Interval Lockage every	Lock Volume.	C. F. S.	Season Freight Tonnage.	Tonnage per Lockage.	Season Number of Vessels.	Average Tonnage per Vessel.
						h. m.	cu. ft.					
Canadian lock, 900x60x18.	1903	Apr. 2-Dec. 15..	258	3,247	12·58	1 54	972,000	141·5	5,502,185	1,694·5	4,353	1,264·0
	1904	Apr. 30-Dec. 26..	241	3,022	12·53	1 55	972,000	141·0	5,028,190	1,663·8	3,967	1,267·5
	1905	Apr. 10-Dec. 20...	255	4,035	15·82	1 30	972,000	178·0	5,468,490	1,355·2	5,660	966·1
	1906	Apr. 13-Dec. 22..	254	4,156	16·36	1 28	972,000	184·0	6,570,788	1,581·0	5,680	1,156·8
	1907	Apr. 22-Dec. 15..	238	4,592	19·29	1 14	972,000	217·0	15,585,368	3,394·0	6,346	2,455·9
Poe lock, ... 800x100x18.	1903	Apr. 2-Dec. 15..	258	4,928	19·10	1 15	1,440,000	318·3	27,790,831	5,639·3	9,070	3,064·0
	1904	Apr. 30-Dec. 26..	241	4,074	16·90	1 25	1,440,000	281·6	24,640,923	6,048·3	7,406	3,327·1
	1905	Apr. 10-Dec. 20..	255	5,288	20·73	1 9	1,440,000	345·5	36,543,484	6,910·6	9,458	3,863·7
	1906	Apr. 13-Dec. 22..	254	5,845	23·01	1 2	1,440,000	383·5	43,083,490	7,371·0	9,968	4,322·1
	1907	Apr. 23-Dec. 11..	233	5,487	23·54	1 1	1,440,000	392·3	40,859,145	7,446·5	8,475	4,821·1
Weitzel lock, 515x80x18..	1903	Apr. 2-Dec. 15..	258	3,467	13·43	1 46	693,090	107·7	1,381,421	398·4	5,173	267·0
	1904	Apr. 30-Dec. 26..	241	3,219	13·35	1 47	693,090	107·1	1,876,993	583·1	4,747	395·4
	1905	Apr. 10-Dec. 20..	255	4,469	17·52	1 22	693,090	140·5	2,258,706	505·4	6,561	344·2
	1906	Apr. 13-Dec. 22..	254	4,522	17·80	1 21	693,090	142·8	2,096,802	463·6	6,507	322·2
	1907	Apr. 23-Dec. 11..	233	3,941	16·91	1 24	693,090	135·6	1,772,701	449·8	5,616	315·6

A study of this table shows that the total number of lockages per season at each lock is increasing year by year, and consequently the time interval between successive lockages is becoming shorter. This is due to the increase in the passing freight tonnage, there being more vessels in the freight-carrying trade year by year passing through these locks. This will continue to increase until the present locks will be worked to their full capacity, at which time the average interval between successive lockages will have reached a minimum for each lock. Up to the present time the greatest number of lockages for each lock in a day, and the consequent intervals are as follows:—

Lock,	Number of lockages,	Interval,
Canadian..	34	42 minutes,
Poe..	36	40 "
Weitzel..	41	35 "

Single lockages have been made in less time than the above intervals show; as for instance, a single steamer has been locked through the Canadian lock in 8 minutes, the Poe lock in 11 minutes, and the Weitzel in 10 minutes, but it is unreasonable to consider these times in the endeavour to judge what interval would be applicable to the condition of traffic most likely to prevail in the Georgian Bay Ship Canal.

The Soo locks are at the present time considered to be inadequate to handle the increased traffic expeditiously and, for that reason, a new lock of greatly increased capacity to the Poe lock is now authorized by Congress to be constructed on the Michigan side, and an additional lock to that is also contemplated there. For the Canadian side a new lock and canal are at present being considered by the Department of Railways and Canals and will, no doubt, reach the construction stage within the next ten years.

The congested traffic at the Soo is shown by the small interval between successive lockages and, when a new lock has been opened that interval has naturally become longer to suit the altered condition; from this we should judge that there must be some interval which must be in harmony with the condition of traffic, when that traffic is without congestion.

In 1895 the number of lockages in the Weitzel lock was 7,039, when the traffic may be considered as having been congested, as the time interval for this lock in that year was 47 minutes. In September of that year the Canadian lock was opened, and in August, 1896, the Poe lock was opened and, in consequence of these two new locks being thrown open, the number of lockages in the Weitzel in 1897 was reduced to 1,577, the Poe lock that year taking 4,390 lockages and the Canadian lock 4,359. The time interval in the Weitzel lock being reduced from 0 hours 47 minutes to 3 hours 30 mintes, and the intervals for the Canadian and Poe locks for the same year were 2 hours 11 minutes, and 1 hour and 18 minutes respectively.*

From the above it would seem reasonable to assume that a time interval of 1 hour 20 minutes over the estimated navigable season of 210 days, as a conservative maximum upon which to base any speculation with regard to the summit tonnage capacity, irrespective of its direction east or west, which could be fairly maintained with the supply of water at hand unaugmented by any outside source of supply.

It may not be amiss here to speculate in regard to the amount of tonnage which may be passed over the Summit using the above interval.

The Georgian Bay canal locks are designed to take the largest tonnage freighter plying the great lakes, or in excess of 12,000 tons of cargo per lockage. The average tonnage per lockage at the Canadian and Poe locks in the last five years ranges from 1,355 to 7,446 tons, and it seems safe to assume that the type of *through lake carrier* which would use the Georgian Bay Ship canal would average at least 2,500 tons cargo

*The summit locks of the Georgian Bay Ship canal are designed to effect a change of level in the chamber in eight minutes, or about the same time as that of the Canadian lock at Sault Ste. Marie.

capacity or better. On this basis we may consider two vessels, the *Arthur E. Orr* and the *Kearsarge,* which may be taken to illustrate a type of through lake carrier. They are much smaller than the capacity of the locks as designed, and are a common type of package, freight and bulk cargo carrier built and building at present on the Great Lakes.

These boats ply between Lake Michigan and the Georgian Bay railway terminals, carrying principally package freight. They are of that class which would most probably use the Georgian Bay Ship canal to the St. Lawrence terminals. Their dimensions are as follows:— Str. *Arthur E. Orr*: length, 344 feet; beam, 41 feet; draft, 20 feet; cargo tonnage, 4,800 tons; net tonnage, 2,740 tons; gross tonnage or displacement, 7,545 tons. Str. *Kearsarge*: length, 328 feet; beam, 44 feet; draft, 20 feet; cargo, 4,500 tons ;net tonnage, 3,092 tons; gross tonnage or displacement, 7,592 tons.

With vessels of this class averaging 2,500 tons, the summit would pass 9,550,000 tons in 210 days of navigation. This must not be taken to represent the extreme capacity of the canal within the limit of an interval of 1 hour, 20 minutes; for, if trade warranted the passage of boats of 4,000 tons cargo capacity on the basis of 1 hour, 20 minutes between successive lockages in 210 days, the tonnage would be increased to 15,120,000 tons per season. Of course with a shorter interval this tonnage would again be increased by a considerable amount.

It may be stated broadly that, upon the basis of successive lockages occurring 1 hour and 20 minutes apart, and with all other summit drainage accounted for, the supply is greater than the demand, even with 10 per cent added to the latter by upwards of 40 cubic feet per second.

The *third* condition, or that of augmenting the summit supply from outside sources, has been carefully worked out by the hydraulic party and a special party of the district staff. With an expenditure of about $20,000, the waters of the Wisawasa can be drained into Lake Nasbonsing, thereby giving a total of 542 cubic feet per second available during a navigation season from all sources for the summit supply; this is fully illustrated in the report of the hydraulic engineer.

With an expenditure of about $900,000 the entire watershed of the Amable du Fond river could be made available as an additional source of supply. This would be accomplished by damming the Amable du Fond river at Gravelle chute and diverting it by flume, open cut, and tunnel to the headwaters of Sparks creek which flows into Talon lake some distance west of the proposed dam-site at the Talon chute. This watershed covers some 300 square miles and contains a number of large lakes. By using these lakes as storage reservoirs having controlling dams at their outlets, there could be obtained an additional 700 cubic feet per second during naivgation season to augment the summit supply.

It will be seen that, with the additional supply of the Wisawasa and Amable du Fond watershed, there would be about 1,250 cubic feet per second available for canal purposes continually throughout the open season, or more than sufficient to supply the summit, were the locks to be doubled and each the size of the Canadian Ship canal at Sault Ste. Marie.

FEEDER CANALS.

The basin which enfolds the adopted summit will derive its supply of water from the combined watersheds of Trout, Turtle, Talon and Nasbonsing lakes, in all covering an area of 342 square miles, and whose present outfall occurs at the Talon chute at the lower end of Talon lake.

The run-off of this basin has been shown to be upwards of 500 cubic feet per second throughout a season of navigation in any one year, and which will be used to make up the depletion of the impounded storage of the summit lakes from canal usages, up to such a time as both the inflow from the watershed and impounded storage will be called upon for canal purposes, as explained under the heading of 'Summit.'

In order to increase this supply during the latter term—in the event of such an increase being deemed necessary—investigation of adjoining watersheds were made with a view to diversions of their outflows into the summit basin.

The Wisawasa river, draining the watershed of that name and whose catch basin is Lake Wisawasa, flows into Lake Nipissing at East Bay. This watershed will approximate 60 square miles in area, and yield a run off during the season of navigation of 50 cubic feet per second. These waters can be diverted by means of a dam and open cut into Depot creek, a tributary of Lake Nasbonsing, thus allowing them to flow into that lake, the highest storage level of the projected summit lakes.

Lake Nasbonsing lies about six miles to the north of Lake Wisawasa, and about 60 feet below it. The cut necessary to effect the diversion will pierce the divide between them, which occurs close to the latter. The cut would be on a ·04 per cent grade, about 5,000 feet in length, 20 feet in width, and average less than 10 feet depth of cutting. It would contain approximately less than 35,000 cubic yards, over one-half of which would be rock.

From the north end of the cut, where it joins Depot creek, the descent into Lake Nasbonsing would be rapid.

A study of the Amable du Fond river and its head-waters leads to a belief that the full discharge of its watershed could be so diverted as to flow into the Summit level above the Talon chute, instead of discharging, as at present, into the lower Mattawa river at the Epines rapids, five miles below.

Sparks creek flows into Talon lake, one mile above Talon chute. Its course parallels that of the Amable du Fond river, and its surface elevation at its upper end approximates that of Kiashkoqui lake, which is the lowest lake of the Amable du Fond watershed, and whose outflow is the Amable du Fond river.

From many reconnaissances, carrying levels, of the country lying between the upper end of Sparks creek and the upper part of the Amable du Fond river, it was found that a diversion of the waters of the latter into the source basin of the former would be possible.

An exhaustive examination of this route was made, placing the configuration of the country under close contour and exact levels. With this information in hand the project of diversion, by dam across the Amable du Fond river at Gravelle chute, and with flume, open channel and tunnel, was carefully laid down and an estimate of the cost for same obtained.

That part of the Amable du Fond watershed above Gravelle chute is 305 square miles in area, and will yield, with control of the several lakes therein, a maximum discharge of better than 750 cubic feet per second during the period above referred to or that commencing at the time when both inflow and storage of the summit basin will be called upon to supply canal purposes.

The investigation of the hydraulics of this part of the watershed, and the amount of impounded storage that could be controlled therein, was carefully gone into by a special party under the direction of the hydraulic engineer; very complete data relative thereto will be found in the report of that division of the staff, and need be referred to but sparingly here.

The upper catch basins of this watershed are those of Lakes Kiashkoqui, Mink, Three-Mile, Manitou, Tea and Kah-wah-way-igo-mog above the Indian river. These lakes, excepting the first, can be raised by inexpensive timber dams to impound a 30-foot storage in each above their normal levels, and Lake Kiashkoqui, 32 feet, in the manner described before.

A judicious control of the outflow of these lakes at their respective dams, once they have been filled to the required elevation, will yield, during the required term, the discharge mentioned above.

Kiashkoqui lake, the last of the chain of lakes in this watershed, will be held by a dam thrown across a natural gorge of the Amable du Fond river, just above the

Gravelle chute, and about five and one-half miles below the outlet of that lake where the converging side hills naturally lend a site to that project.

The river above the dam is well contained within very high and steep rocky hills which parallel the river close upon each side. The present low water fall of the river from the lake to Gravelle chute is 41 feet, or from elev. 989 to elev. 948. Its fall in flood is indeterminate, being held by timber dams at both places at the present time and used by the lumber interests in the spring drives.

The dam at Gravelle chute will raise the river at that point 73 feet, and the present low water surface of the lake above by 32 feet, as above stated. It will be pierced for the intake or regulation works, giving access to the feeder canal, and also by other regulating works carrying the surplus waters to the Amable du Fond river below, when not required for diversion. The dam will be in two parts; the main dam will be thrown across the gorge of the river proper and contain the intake or feeder regulation, and will have about 1,300 feet crest length; the other spanning a break in the flood contour to the east nearby and containing the waste gates, will have about 550 feet along its crest. Both dams will rest entirely upon rock foundation and will be of the rock and earth-filled type, with a hand-laid wall on a 2 on 1 slope between; the earth face up stream will be a 1 on 3 slope, and the rock fill below on a 1 on 1 slope.

With proper regulation of the stream flow during construction, and the erection of inexpensive coffer-dams, these works can be built entirely dry.

The rock-fill will approximate 48,000 cubic yards, and the earth-fill 135,000 cubic yards, material for which may be found in the immediate vicinity; details of the other parts of this dam may be found in the estimate.

The intake or entrance to the feeder is on the south side of the main dam and is situated in the side hill proper; it is of concrete construction throughout, on rock foundation, with concrete key-wall running from the abutment into the dam on that side. The gate openings are two in number with pier between, and will each be 12 feet wide with their sills at elev. 1,013, or eight feet below the highest reservoir level, elev. 1021. This will allow up to one foot head of water over that at the commencement of the flume which joins the intake immediately below; the dimensions of the openings are thereby amply large to insure the flume running full, or upwards of 700 cubic feet per second.

Each opening will be fitted with a steel bound wooden gate working in cast-iron grooves, raised or lowered by hand machinery from a bridge built above the coping, the maximum power required to raise the gate, when closed against full head on up-stream side, being about 3,600 lbs.

The waste gates in the other dam will be similar in construction and will discharge to a stone pitched channel leading to the river below.

The line of the diversion follows the shortest obtainable grade, with the least amount of excavation in channel and tunnel, to the headwaters of Sparks creek a distance in all of 8½ miles from the Gravelle chute, at which point the grade runs out above the bed of Sparks creek.

The grade elevation or inside bottom of channel at the intake will be 1,013, that at the point of junction between the feeder and Sparks creek will be 994·4, or 19 feet in all; this fall is distributed with reference to the nature of the different conduits and their respective lengths, so as to obtain the required velocity therein and consequent uniform volumes of discharge in each.

The diversion is obtained by means of flume on trestle bents where the side hill slopes permit, by tunnel where necessary to pierce the ridges separating the two valleys, by lined open channels above and below the tunnel portals joining those points where the flume leaves off and the tunnel begins, and by unlined open cut.

The flume will be of wood, 15 feet wide and 7 feet deep, lined with matched lumber and supported on substantial trestle bents, 14 feet centre to centre, the line following the configuration of the side hill.

The lined open channels will have a bottom width of 8 feet, a depth of 7 feet, with side slopes of 1½ on 1. They will be lined with concrete on a foundation of broken stone.

The tunnels will be trapezoidal in form, with an arched roof, somewhat less in wet area of section but with increased grade over flume or open channels, well timbered, substantially lined with concrete and the intervening space between packed with suitable material.

The unlined open channels have a bottom width of 20 feet with side slopes of 1½ on 1.

The elements of the different sections are obtained from trial sections, limiting velocities, obtainable grades, and the Chezy formula $V=c\sqrt{rs}$ with the values of c from Kutters formula and various tables.

The following summary is descriptive of the main features of the feeder.

ELEMENTS, AMABLE DU FOND FEEDER.

Description.	From Sta.	El. W.S.	To Sta.	El. W.S.	Distance, feet.	Fall.	Grade, p.c.	S.	V.	Q.*
Flume	0 + 00	1020·00	114 + 50	1016·09	11,450	3·91	·03	·00034	7·11	746·5
Lined open channel	114 + 50	1016·09	117 + 30	1015·99	280	0·10	·03	·00031	5·79	750
Tunnel	117 + 30	1015·99	134 + 00	1013·98	1,670	2·01	·12	·00121	9·74	750
Lined open channel	134 + 00	1013·98	163 + 00	1013·08	2,900	0·90	·03	·00031	5·79	750
Flume	163 + 00	1013·08	322 + 00	1007·64	15,900	5·44	·03	·00034	7·11	746·5
Lined open channel	322 + 00	1007·64	322 + 70	1007·62	70	0·02	·03	·00031	5·79	750
Tunnel	322 + 70	1007·62	338 + 90	1005·65	1,620	1·97	·12	·00121	9·74	750
Lined open channel	338 + 90	1005·65	344 + 00	1005·49	510	0·16	·03	·00031	5·79	750
Unlined open channel	344 + 00	1005·49	425 + 00	1001·00	8,100	4.49	·05	·00053	3·51	750
					42,500	19·00				

*Theoretical.

From the table it will be seen that the volume discharge for each section, is in excess to that required, i.e., 700 cubic feet per second, and which is estimated to overcome undue friction due to curvature, bad workmanship and leakage.

The hydraulic elements of the different sections were taken for the maximum discharge, but it is not supposed that this discharge is to be required continuously during the period called for, when, in the event of a less discharge, a general decrease in the hydraulic elements will obtain.

From the intake the water is carried by a flume two miles, the location being on the steep side hill slope of the west side of the river, where the first height of land is met. Through this the water will have to be carried by means of a tunnel 1,600 feet in length, with lined open channel above and below the portals joining the tunnel with flume. The lined open channel above and below will total 3,200 feet.

Below this tunnel the contour of the ground surface necessitates a cut in which is the lined open channel varying in depth from 40 to 15 feet, over a distance of $\frac{6}{10}$ of a mile to where the side hill and valley approaching Sparks creek are met. From here to a distance of three miles below the water will be again carried by a flume entirely upon side hill location where the last divide between the valley of the Amable du Fond river and the upper part of the watershed of Sparks creek occurs.

This ridge is pierced by a tunnel 1,600 feet in length and, as before, having lined open channel above and below its portals, 70 feet above and 2,500 feet below. At the lower portal of this tunnel the ground surface is about 17 feet above grade and a cut of this depth for a distance of one and one-half miles in unlined open channel will carry the diversion to a point in the bed of Sparks creek, where a sharp

fall begins the natural descent into the proposed summit elevation of Talon lake, 335 feet below.

No unwatering would be necessary in the construction of this work, as natural drainage would be effective in the tunnels and cuts.

The diversion will be a little over eight miles in length, 63 per cent being flume, 20 per cent unlined open channel, 9 per cent lined open channel and 8 per cent tunnel.

The Amable du Fond river is largely used at present during the spring floods to pass timber cut during the previous winter into the Mattawa river below. In the event of constructing the diversion, some other method of disposing of or transporting the logs would have to prevail, for the reason that the necessary water for the drive would be required for storage in the lakes above, and the present outlet of the lumber interest in that vicinity, the Mattawa river, would have to be entirely free to insure safe navigation.

REGULATION.

Regulation of the water of the different reaches of the Nipissing district, so that the adopted elevations may be maintained therein with sufficient flexibility of control, will be accomplished in two ways:—

Where the variation of the discharge will be very great, by large square openings built in the main dam, fitted with sluice gates or stop-logs, and of sufficient number to pass excessive discharges within short periods of time, and allowing withal of close regulation during the periods of low discharge.

Where the maximum discharge is comparatively small, by overflow dams, the available crest length permitting the flood discharge to pass without excessive depth over the dam, the fixed elevation of whose crest will maintain the reach above at the required stage.

It is estimated by the hydraulic staff that the flood discharge of the Ottawa river between the Mattawa river and the Des Joachims rapids will be so regulated by controlling dams, distributed throughout its upper watershed, as not to exceed 45,000 cubic feet per second.

The regulated discharge during the season of navigation will approximate 16,000 cubic feet per second, and its minimum, that might probably occur during the same period, 7,550 cubic feet per second.

It is evident that a possible excess over the above flood discharge must be guarded against in the event of the failure of the watershed control, and with such regulation below Mattawa as to control the variation of the discharge there between the above limits.

For this reason, it was deemed best to establish openings of sufficient size to pass about 120 per cent in excess of the regulated maximum flood discharge, as estimated by the hydraulic staff, or say 100,000 cubic feet per second.

Steel sluice gates of the 'Stoney' pattern, and of varying widths and heights to suit different openings, together with suitable machinery, operated from a bridge spanning the substructure, to raise and lower them, were designed and estimated for by Mr. Henry Goldmark, C.E., of Montreal. This allowed the design of a substructure with sufficient openings, and of the required dimensions, to suit the intended location.

ROCHER CAPITAINE.

The dam spanning the river at the Rocher Capitaine rapids will be fitted with regulation works of this character. The main channel of the river will be blocked by a rock and earth-fill dam at right angles to the flow, from the flood contour, at a point on the upper end of the Rocher Capitaine island on the south to the present low water line on the north shore, at which point the regulation works commence.

The regulation works will extend for about 500 feet in the same direction; a mass concrete dam will continue from their north end to the raised water surface contour on that side.

The rock-fill of the main dam will have slopes approximating 1 on 1, the up-stream face holding an earth-fill to a 1 on 3 slope, a woven timber mattress being placed between; the dam will have a crest width of 30 feet and will be about 55 feet in height at its middle.

The regulation works consist of 7 concrete piers and 2 abutments, the latter securely keyed into the rock-fill dam on the south and forming part of the concrete dam on the north. The openings will be 8 in number, 40 feet wide, and will be fitted with vertically operating steel 'Stoney' sluice gates controlled by hand-power machinery from an operating bridge running over all.

The elevation of the controlled water level above is 570·0, that of the sills of the regulation gates will be 450·0, which will allow, at full opening, a discharge of 100,000 cubic feet per second, or 120 per cent in excess over regulated maximum discharge as estimated, with control of the different basins throughout the watershed of the upper river. The maximum regulated discharge of the river is estimated to be not more than 45,000 cubic feet per second, and to pass this flow the gates would be raised above their sills by 6·5 feet.

The gates are formed by horizontal built up steel girders with a $\frac{3}{8}$-inch steel skin on the up-stream face, and resting against nests of rollers running in vertical checks in the piers. The sills running across each sluiceway, taking the toe of the gate and the track bearings of the rollers, will also be of steel members firmly imbedded in the concrete; the gates will be sufficiently counterweighted to permit of easy operation.

A highway crossing over the piers is provided by means of a plate girder bridge 20 feet wide, running from pier to pier below the gates, and 6 feet above the raised water surface; the crest of the rock-filled dam will be sufficiently wide to continue the crossing on that side of the regulation works, and the concrete dam to the north will be buttressed, so as to carry the girders for a continuation of the bridge thereon.

The foundation of the regulation works and the concrete dam on the north side will be entirely on solid rock which is some distance below the sill elevation, or level of the sluice floors, thereby requiring a built up concrete foundation throughout.

The slope of the rock surface here is gradual and with the river, and is such that, with the full opening between the piers, the water would pass rapidly to the lower pool 10 feet below the sluice floors. The rock and earth-fill dam blocking the entrance to the sny around the Rocher Capitaine island is of the same nature as the main dam in the river and completes the regulation works at this point.

There is no question with regard to the stability of the rock and earth-fill type of dam, but rather with regard to its being made sufficiently water-tight, to serve the intended purpose, particularly in this case and that of the Deux Rivières above, where the mid-section height is considerable. With reasonable care in the construction of the mattress and the selection and laying of the staunching material to the slope shown on the up-stream face, the leakage through them would be so small as to be inappreciable in the regulation of so large a discharge as even the minimum flow of the Ottawa river. Numerous examples of the rock and earth-fill type of dam could be given, where their purpose has been admirably served.

The piers and abutments of the regulation proper are designed for the full head on the gates with a factor of safety of 2½ which is ample under the conditions.

The total estimate for dams and regulation at this point approximates one half million dollars.

DEUX RIVIÈRES.

The river flow at Deux Rivières, 13 miles above, is identical with that at the Rocher Capitaine; the same figures will, therefore, apply. The dam and controlling works at this point were forced by the absence of rock elsewhere, at sites that would probably have been superior from the standpoint of regulation.

The dam will extend from the lower walls of the lock on the south side of the river to a bold rocky point on the north, at the foot of the lower or Deux Rivières rapid.

The main dam in the body of the river will be a rock and earth-fill similar to that at the Rocher Capitaine, and joining it with the lower walls of the lock on the south side will be the location for the regulation of the pool above.

The regulation here will be similar to that at the Rocher Capitaine, but on account of the limited space available for those works, the number of gates are limited to five. They will, however, control a head of 30 feet, instead of 20 feet as at the Rocher Capitaine, and thereby obtain, with full opening, the excess discharge required of 100,000 cubic feet per second. To pass the regulated discharge of 45,000 cubic feet per second, the gates will be raised 8·5 feet above their sills.

The foundations of the regulating works will be entirely on rock, and will require to be slightly built up above the rock surface to obtain the sill elevation, or floors of the sluices.

The rock here also slopes with the river and its surface below the gates falls rapidly, thereby allowing free discharge without back water, the floor of the sluices being at the same elevation as that of the pool below.

The design is worked out to the same stability as the Rocher Capitaine sluices, but no crossing is provided, there being no communication whatever between the north and the south shores.

It may be well to state here that the regulation works of the Ottawa river at the Rocher Capitaine, and at Deux Rivieres could be constructed without difficulty during the present low stages of the river, and without the necessity of coffer-dams. The rock-fills of both localities could be conveniently placed by means of cables from shore to shore over the site, sufficient material for all purposes being found nearby.

The cost of dams and regulation here will approach $450,000.

MATTAWA RIVER.

The flood discharge of the Mattawa river from the Summit down is comparatively small when considered as a matter of regulation, it being less than 3,000 cubic feet per second, and the minimum flow of the river in its present stage would prove insufficient for canal purposes.

The former condition will permit of the regulation of the different pools therein by overflow dams without, as above stated, excessive depth at any stage flowing over crest; and the latter is raised to a sufficient volume by the proposed treatment of the summit watershed and the control of the headwaters of the Amable du Fond river, with its diversion, if necessary, into the Summit lakes.

MATTAWA.

The first pool above the head reach of the Ottawa river will be held and regulated by an overflow dam spanning the Mattawa river a short distance above its mouth. The dam will have a vertical face and stepped back, will be of concrete throughout, and built of first and second-class concrete, the latter comprising the filling or core.

The upper pool will be held at elev. 510·0, 10 feet over that of the pool below. The length of the dam will be 930 feet, and will have a depth on crest of 0·55 feet at the regulated discharge of 1,280 cubic feet per second, and 1·5 feet for a possible excess of 100 per cent over its present maximum discharge.

The foundation of this dam will probably rest on firmly cemented boulder material, the borings in this vicinity failing to reach rock surface. The head, however, is small and there should be no difficulty in securing the foundation against leakage.

It will require to be built within a coffer-dam, and is estimated to cost $171,000.

PLAIN CHANT.

The next pool above will stand at elev. 540, or 30 feet over that controlled by the Mattawa dam.

A solid concrete dam spanning the river immediately below what is now the Plain Chant chute, from the upper head walls of the lock on the west side to a very precipitous side hill on the east, will effect this purpose. Its crest acting as a spillway will afford the required regulation. In section the design is of the ogee curve type, and is of sufficient area and weight to show a factor of safety of 2½ against overturn or sliding under flood pressure. This dam will be built of concrete throughout, of first-class and second-class, the main bulk of material being the latter and forming the interior, with the shell or facing of richer mixture.

It will have a crest length of 1,373 feet, on which the depth of water will stand ·43 feet during the regulated discharge and 1·2 in the event of 100 per cent excess over the present maximum discharge.

The borings over this dam site proved most difficult, on account of the size and compactness of the boulder material forming the surface. Rock was disclosed, however, on the west shore from the river edge to above what would be the flood contour, and on the east side rock was only disclosed some distance up the slope. This would lead to the belief that solid rock in the bed of the river may be found at no great depth.

The foundation within the confines of the river will require to be excavated and built within a coffer-dam, the remainder, however, will offer no difficulty in construction.

The material for construction, both sand and rock, can be obtained in the immediate vicinity.

The estimated cost of this dam approximates $266,000.

LES EPINES.

The next regulation above will be obtained by a solid concrete overflow dam of the same design as the Plain Chant dam, and spanning the river between LaRose and Les Epines rapids, a short distance below the mouth of the Amable du Fond river, and will raise the pool above to elevation 557·0 or 17 feet over that of the pool below. Its crest length will be 475 feet, which will allow a depth flowing over it of ·87 feet, for the regulated, and 2·39 feet for the 100 per cent excess maximum discharge, both being of the same volume as those mentioned for the two dams below.

The same difficulty in construction of foundation applies here as at the dam below, rock being found above the shore lines on each side, but not in the river nor immediately above the shore, necessitating unwatering to construct the river portion.

The estimated cost of this dam approximates $190,000.

AMABLE DU FOND.

The regulation of the outflow of the Amable du Fond river is dealt with under the description of the Feeder canal and need not be mentioned here.

TALON CHUTE.

The next regulation above is that of the Summit level, which will be effected by the crest elevation of the Talon chute dam thrown across the converging slopes of the outlet of Talon lake. This dam will be of the same type and character as the Plain Chant dam, angular in form, to take advantage of the topography, and 1,115 feet in length on its crest.

The outflow of the summit watershed will pass over this dam after the summit reservoir is filled, and then only durign the spring months ending sometime in June, unless the supply is in excess of that required to meet the demands of the Summit for lockage, power, leakage, &c., as detailed under the discussion of the Summit level. Under present conditions the maximum discharge of the summit basin is 1,490 cubic

feet per second and the minimum 50 cubic feet per second. The available supply of the summit watershed, which is about 540 cubic feet per second, or what would be the regulated discharge if not used as above stated, would find its outlet over this dam.

The crest of this dam will stand at elevation 677, and its length of 1,115 feet will allow, in the event of the reservoir being filled and the maximum discharge passing over the dam, a depth on crest of 0·55 feet.

It will have a height of 87 feet above the foundation for a short distance in the present bed of the river.

The above elevation creates the storage called for, of 4 feet throughout the summit level, or 4 feet over the 22 feet standard depth on the sills of the summit locks.

The foundation of the Talon chute dam will be entirely within rock and, as the Talon chute itself, the present barrier of Talon lake—the lowest lake of the summit chain—can be sufficiently lowered without much difficulty, the foundation of the dam may be laid dry, and so insure against the possibility of leakage, which is so much to be desired at this point.

No other regulation obtains to the summit level estimated to effect the control; a pair of 'Stoney' gates, feeding the basin between the upper and lower Paresseux flights of locks, will pass an amount of water included in the summit drainage, under 'Amount required for lockage and power,' and so enters into summit discharge that would flow out over the Talon dam, when not required to supply the basin.

It may be mentioned that the 'Stoney' gates, together with the lock valves of the Paresseux flights and the North Bay lock would serve the purpose of draining the summit reach to the grade of the upper sills of the summit locks, elevation 651·0, and also the basin between the Paresseux flights to its grade elevation 595·0, should repairs be necessary to those structures or the approaches leading to them.

LAKE NIPISSING REGULATION.

The Lake Nipissing level will be controlled at elevation 648·0, about 6 feet above its present surface, by a concrete sluice dam fitted with 'Stoney' gates, at the head of Big Chaudière rapid, the main outlet of the Lake Nipissing watershed. The length of the dam from shore to shore will be 275 feet, and the openings will be 40 feet wide, with a depth over the sills of 20 feet at the regulated level.

The location for this dam is an excellent one, the side walls and bed of the river being entirely of rock and taking the nature of a gorge, while the depth is not so great as to make it difficult to place the foundation.

Excavation will be necessary in the bed of the river from shore to shore, 8 feet deep and 45 feet wide, in which to place the foundation to the floor of the sluices, at elevation 628, from which will rise the piers and abutments of the regulation proper.

The sluices, gates, and operating mechanism will be identical in size with those at the Rocher Capitaine on the Ottawa river; no highway crossing, however, is necessary.

The bed of the river below the sluices falls rapidly in the direction of the flow, which will allow the discharge to pass freely to the lower pool 24 feet below.

The maximum discharge of the Lake Nipissing watershed is 13,390 cubic feet per second, to pass which all three gates would be raised to 5·2 feet above the floor sills. At full openings the three sluices will discharge 35,736 cubic feet per second or about 160 per cent in excess of the estimated maximum discharge.

The construction of the foundation to receive the above-mentioned piers and abutments will require to be enclosed within a coffer-dam which, when unwatered, will permit them to be built dry, and the gates seated.

Three other outlets of the Nipissing level at the Little Chaudière, while too small to be considered with regard to the placing of regulation works therein, are yet large enough, with a very small amount of excavation in rock, to pass the minimum dis-

charge, duing the construction of the Chaudière dam. They will, however, eventually be blocked by small concrete dams.

The estimated cost of dams and regulation for this level is $81,000.

FIVE MILE.

The pool below, known as the Five-mile rapids reach, will be raised by dams to elevation 624, or 22 feet above its present surface, and controlled at this elevation by 2 sets of concrete sluiceways fitted with stop-logs.

One set of three sluices will adjoin the Five-mile rapid lock on the south, blocking a natural gulley there, which parallels the projected centre line of canal, and is dry at the present low water level.

The other set of sluices, four in number, will be placed in a dam which will block the north branch of the French river about 7 miles below the point where the river divides into two parts above the Little Pine rapids.

The sluiceways in both dams will be 20 feet in width, with their floors at elevation 609, 15 feet below the upper regulated level. They will be closed by timber stop-logs, 18 in. x 18 in., which will be raised or seated by a travelling hoist running on a bridge over the whole structure, and operating two vertical rods which are in turn connected at each end of each stop-log.

Both branches of the upper French river give a maximum discharge of 14,876 feet, per second, to pass which will require a depth of 10·1 feet on the stop-logs of all sluices; with all the logs removed the sluices would discharge 27,076 cubic feet per second, with the same head of 15 feet, giving a 100 per cent excess capacity over the maximum discharge.

The concrete sluiceway across the gulley to the south of the Five-mile lock will consist of 2 piers and 2 abutments forming the 3 openings. It will be entirely within rock foundation, 115 feet long and 40 feet wide at the floor level; the average depth of excavation to seat this dam will be about 12 feet over the above area.

The surface of the gulley below the sluices falls very abruptly and will permit the discharge to pass rapidly to the next level 24 feet below.

The dam across the main French, at the place above mentioned, will be in two parts.

A concrete dam, with 4 sluiceways contained between 3 piers and 2 abutments of the same dimensions and elevations as those just described, will close the main river. It will be 190 feet in length and rest almost entirely within rock foundation. The floor elevation of 3 of the sluiceways, being about 5 feet above the bed of the river, will require a mass concrete footing to be built up to that level for a distance of 75 feet in length of dam, and of full width of the floor in the direction of the flow. This may be laid within forms under water to the floor line which is but 4 feet below the present surface, when the forming may be unwatered and the piers and abutments built dry.

A timber dam 180 feet in length, and averaging 4 feet in height will close a depression on the north from the concrete dam to the flood contour on that side.

The main dam which will raise the Five-mile reach to elevation 624 is thrown across the Main French river at the Little Parisian rapid, immediately to the north of the lock.

The site is admirable for the purpose, the side hills of rock being very precipitous and confining the river there to a narrow strip of about 80 feet.

This dam will be of the rock and earth-fill type already described; its height in the river section will be 65 feet and its crest length 550 feet.

Materials for construction of these dams and regulations are found nearby. The total cost being estimated at $70,000.

PICKEREL AND FRENCH RIVER.

The Pickerel river, the last of the chain, will be maintained and regulated by 4 concrete dams placed in the four present outlets of the French river into Georgian bay.

The dams will raise the present surface of the river, below the Horseshoe falls of the Pickerel river and the Recollet falls of the French river, by 14 feet, and above those two points through to the Five Mile lock by about 6 feet. They will afford a total crest length, available for spillway, of 2,200 feet, and, with the crests standing at elevation 598·91, will pass the maximum discharge of 21,150 cubic feet per second, with an overflow depth of 2·03 feet. The above crest elevation forces the adopted elevation of 600·0 for the reach at the minimum flow.

These dams will be of the ogee curve section, and be constructed of first and second class concrete in the same manner as that described for the Plain Chant dam of the Mattawa river.

The French river outlets were gauged separately to obtain the discharge of this reach, making it unnecessary to investigate the hydraulics of the Whanipitae river and other streams flowing into it, an account of which will be found in the report of the Hydraulic staff.

These outlets are the Eastern, about two miles above Ox lake on the Pickerel river; Bass channel, a spur from the main outlet; Middle channel, at the Dalles rapids, close above French river village, on the line of the projected location; and Bad river, or the Western outlet, some three and one-half miles to the west.

The Eastern outlet, which is dry during the minimum flow, offers an excellent dam site close to the Pickerel river, which has the double advantage of affording an exceptional crest length and comparatively small height. The outlet is here broken into several channels by intervening rock ridges within the confines of the side hills. This will break the dam into four parts, in lengths of 585, 149, 70 and 140 feet, permitting a total crest length of the several spillways of 874 feet. The dam will have a height of about 20 feet for a distance of about 50 feet, and the remainder will average not more than 10 feet in height; it will rest entirely within rock and can be constructed without the difficulty of unwatering the seat. Cost estimated at $19,000.

Bass channel will be dammed a short distance below Bend Point of the Middle outlet. The dam will be about 525 feet long, with a spillway of 486 feet. Its greatest height for a short distance in the middle of the river will be about 54 feet. To obtain the required footing in the main bed of the river will necessitate unwatering of an area of 110 feet in line of dam by 40 feet width, the present depth being about 32 feet; the remaining length of dam can be constructed dry without difficulty. Rock only is in evidence over the entire site. Its cost will be $58,000.

Bad river will be blocked by a single dam thrown across the river seven miles below the entrance to the Middle outlet at the foot of Ox lake. It will have a length over all of 520 feet, a length on crest of 480 feet and a height of 65 feet, for about 25 feet at its middle part; the rest of the dam will average 30 feet in depth and its seat will be entirely within rock.

To place the footing of this dam below the lowest level to which the water may be lowered may prove difficult, as the flow here is by far the greatest of any of the outlets of the French and Pickerel rivers, being over 15,000 cubic feet per second during maximum flow, and over 6,000 cubic feet per second during minimum flow. The minimum flow is 1½ times greater than the maximum flow at the Dalles, the largest of the remaining three outlets. Under the conditions presented, it is probable that the Bad river dam would be the first undertaken in the regulation of this level.

The problem of unwatering would, in that case, be made easier by so deepening the other outlets as to draw down the reach during the period of low water, and thereby permit the placing of the foundation and the lower part of the dam dry within a coffer-dam; the depth of water over the footing, about 30 feet for a length of 50 feet, would not prevent this being done. The construction of the upper portion of the dam could be proceeded with, also dry, simultaneously with the other dams of this reach, the Eastern outlet and the Bass channel. The cost of Bad river dam will approximate $67,500.

The dam blocking the Middle or main outlet will extend from the walls of the Dalles lock to the raised water surface contour on either side. The portion to the west of the lock forms the spillway and is of the ogee curve section before described. It will have a crest length of 348 feet, and carry a highway crossing to that shore by concrete piers rising from the dam supporting arches of the same material. The portion joining the upper walls of the lock to the east shore is designed to completely block the river on that side, thereby permitting of the filling below it between the lock and the shore. It will have a stepped back and carry an arched highway on buttresses to the head walls of the lock from the shore on that side; they will average 20 feet in height.

Both the above dams will have foundations within solid granite rock—as will the lock of which they form a part—and are estimated to be built entirely dry by means of a temporary dam below the lock, and another at the head of the Dalles rapids above where the outlet converges to a narow stream; the enclosed basin being unwatered for that purpose.

The Dalles dams alone are estimated to cost $7,000.

The cost of unwatering is included in the estimated cost of the lock structure.

A small dam built dry and blocking a sny to the east of Tramway Point would be necessary to check what would otherwise be an outflow; its cost would be $8,000.

In regard to the dams at the Bass outlet and Bad river it is a question if they could not be more economically constructed as rock and earth-fills, with a stop-log regulation of sufficient size to take the whole outflow of this reach; should this be the final outcome, their cost would be within that estimated for the designed structures at those places. Both localities lend themselves naturally to this form of structure and the materials necessary are within easy reach. It was, however, deemed sufficient for this estimate to design the control on the lines given; the cost would cover either system.

The salient features of the regulation, with regard to the different pools of the Nipissing district, are set forth in the following tables which detail the nature and extent of the designed control.

The flow passing the crest of the overflow dams, the stop-log weirs, and the weirs controlled by 'Stoney' gates when full open, were estimated from the 'Francis' formula $Q=M.\ b.\ h^{3/2}$ with the value of M from the Cornell University, U.S.D.W. and U. S. Geological Survey experiments, and the flow under the 'Stoney' gates, when not full open, by the formula $Q=c.\ a.\ b.\ \sqrt{2gh}$ with the value of c taken at 0·602.

WASTE WEIRS THROUGH DAMS.

In the case of the Ottawa river dams at the Rocher Capitaine and the Deux Rivières rapids, a conduit through the body of the main dam, at its bed elevation, does not seem to be warranted, for the reason that no necessity would be served by draining the contained reach lower than the upper approach grade to the adjoining locks. The regulating sluices, when open full, together with the operating sluices of the adjoining lock, will accomplish this when aided by the watershed regulation during the minimum flow.

Moreover, such waste gates will serve to lessen, if opened, the most desirable silting up, or continued staunching of the up-stream face against leakage.

Drainage culverts through the concrete crest overflow dams at the bed river grade, and for the purpose of lowering the reach above to grade, were considered unnecessary in the design of these dams, consequent to this estimate, for the reason that drainage through the lock sluices would serve that purpose admirably well during the period of minimum flow for all conditions of natural repair.

The lower reach of the French river could not be lowered in this manner, the volume of discharge being too great; it is not supposed, however, that this reach would

ever require to be lowered, as repairs to the Dalles lock, which is the step to the Huron level below, would necessitate the guard gates being closed and the lock pumped out.

An alluvial deposit against the up-stream face of the dams, that would be due to the absence of drainage sluices through them, may be unexpected, for the reason that these rivers carry little or no material in suspension, a condition due to the nature of their watersheds.

The dams are designed to withstand pressure due to saturated material in order that there may be no question as to their stability against ultimate pressure.

Regulation by Concrete Crest Overflow Dams.

Locality.	Discharge in C.F.S. Max.	Discharge in C.F.S. Min.	Discharge in C.F.S. Regulated.	Length of Crest in Feet.	Depth in Feet on Crest at Maximum Discharge.	Depth in Feet on Crest at Minimum Discharge.	Depth in Feet on Crest at Regulated Discharge.	Depth in Feet on Crest at 100 p.c. Excess.	Discharge in C.F.S. per lin. ft. Maximum Discharge.	Elevation. Raised Water Surface.	Elevation. Crest of Dam.*
Mattawa	3,000	160	1,280	935	0·98	0·138	·552	1·55	1·02	510·0	509·86
Plain Chant	3,000	160	1,280	1,373	0·76	0·107	·43	1·20	2·87	540·0	539·89
Les Epines	2,975	150	1,280	475	1·48	0·208	·87	2·39	4·23	557·0	556·79
Talon Chute	1,490	50	....	1,115	0·55	0·06	....	0·86	1·55	677·0	677·0
Dalles Channel	4,681	2,032	....	348							
Bass Channel	513	....	....	488							
Eastern Outlet	492	....	....	874							
Bad River	15,464	6,262	....	490							
All Lower French	21,150	8,294	....	2,200	2·03	1·086	....	3·22	4·74	600·0	598·91

*Calculated for possible minimum flow.

REGULATION BY "STONEY" SLUICE GATES AND BY STOP-LOGS.—CONCRETE SUBSTRUCTURE.

Locality.	Discharge in C.F.S. Max.	Discharge in C.F.S. Min.	Control by	No. Openings.	Dimensions (H. × W.)	Height for Maximum Discharge.	Discharge Full Opening in C.F.S.	Per Cent Excess Capacity over Regulated Maximum Discharge.
Rocher Capitaine	*45,000	....	"Stoney" gates	8	20 × 40	6·5	100,000	120
Deux Rivieres	*45,000	....	"	5	30 × 40	8·5	100,000	120
Lake Nipissing	13,390	4,573	"	3	20 × 40	5·2	35,736	166
Five Mile and North French (All Upper French River.)	14,876	5,026	Stop-logs	7	15 × 20	10·1	27,076	100

*Regulated within Ottawa river watershed for this discharge.

LOCKS.

Eight single locks and three flights of two locks each will connect the different pools of the Nipissing district, effecting in all eleven changes of level whose range will be from 10 to 60 feet.

The dimensions adopted for the lock chamber are uniform for all locks, and are such as to permit the passage of the largest freight vessels built and building on the Great Lakes.

The chamber will have a length between inside quoins of 650 feet, a width between plumb walls of 65 feet, and a governing depth of water on the entrance floors leading thereto of 22 feet. This allows a usable length between the inside gates of 650 feet, and by the use of the lower auxiliary gates, below the lower main gates, an additional length of 54 feet may be obtained.

All the locks of the Nipissing district are designed to be built of concrete throughout, the only masonry entering into their construction being the hollow quoins and pivot stones which receive the thrust and weight of the gates; these will be of dressed granite bonded into the concrete of the recess walls.

What method should be adopted for the filling and emptying of the lock chamber brought into consideration many systems now in use; these may be classed as: operation by controlling valves in the gates, by culverts in lock walls having lateral openings into the chamber, by culverts under the lock floor having openings up into the chamber, or by raceways parallel to the canal prism and connected with the lock chamber by side culverts, the raceways receiving their supply from the discharging into the canal prism above and below the lock approaches respectively.

The first three are inexpensive as against the fourth on account of the additional excavation required for it, but the argument is well advanced that, if the water requisite for lockage is taken from above, and discharged below the approaches to the lock, instead of immediately above and below the lock, it will do away with disturbing currents within the limits of the approach.

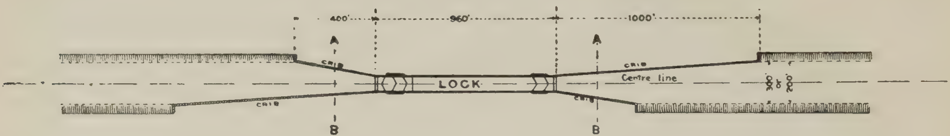
The canal reach above the present locks at the 'Soo' Michigan, is cited in support of the above. The current caused by drawing from it water to supply both locks simultaneously forces a velocity of two feet per second at its narrowest part, and causes a maximum variation of the water surface immediately above the locks of about 1½ feet or more.

This condition is due to the restricted part of the upper entrance to the 'Soo' locks, or at the guard-gates, which are some 2,700 feet above the locks. Here the canal is 108 feet in width, with about 20 feet in depth on the guard sill, or about the same depth as that on the upper sills of the Poe lock.

In consideration of any of the first three propositions mentioned above, the supply of water for lockage would come from the prism immediately above the lock, and it would seem from a study of the approaches to the Georgian Bay locks as designed, in comparison to the upper entrance to the 'Soo' locks, that drawing the supply from immediately above the lock instead of from the ends of the approaches,

could not materially affect the handling of boats within those approaches for the following reasons:—

PLATE C.



A-B. Mean Section of Approach

The mean section of approach 200 feet above and below the lock A-B on plan is in no case less than 2,175 square feet, the rate of flow past this mean section for the operation of a lock of 30-foot lift in 8 minutes would be 0·9 feet per second, with the area of section of approach increasing above and below the mean section.

The minimum section at the old guard gates in the upper 'Soo,' Ste. Marie canal, is about 2,160 square feet, the basin below increasing in section area to the locks, and were both locks filled together in a like time of 8 minutes there would require a velocity of two feet per second at the gate section above to supply this demand.

The latter is not exactly the condition which obtains in the basin above when both 'Soo' locks are filled simultaneously. The volume drawn from the basin in the short time required to effect the change of level in the locks produces a re-current wave in the basin below the section, which is distressing to boats waiting in or passing through this part of the canal above the locks.

Their displacement, moreover, tends to decrease the general section and so increase the trouble therein. Drawing their supply from immediately above for the operation of the Georgian Bay canal locks, and discharging immediately below them would not seem to create, at any locality as unfavourable a condition as that which now applies at the Michigan 'Soo.'

The Canadian lock at the 'Soo,' the longest in the world, has approaches above and below which in a measure resemble the general plans of the approaches to the Georgian Bay locks, although the latter are not confined for so great a length. The operation of this lock causes no uneasiness to vessels lying in and navigating the approaches above and below.

As the velocity mentioned above, 0·9 feet per second, would occur at the mean section above and below the lock, during a short instant of time, say on the assumption of one lockage per hour, it would seem to favour the drawing of the water supply for lockage from the reach immediately above and discharge into the reach immediately below the lock.

In considering any system of filling or emptying the chamber, economy of construction, stability, ease and simplicity of operation are the governing features.

Operating the lock by means of valves in the gate leaves has the advantage of ease of operation, but on the other hand requires gates of exceptional strength and design to frame them; they create moreover disturbing currents within the chamber during operation.

In general practice, the operation of the lock is accomplished by means of wall-culverts, or by floor culverts controlled by valves of different design drawing their supply from a well immediately above the upper gates.

In considering the necessary area to operate the lock in 8 minutes, and taking the coefficient at 0·6 for orifices with square edges, we have:—

$$a = \frac{2A\sqrt{h}}{ct\sqrt{2g}} = 200 \text{ sq. feet.}$$

With one culvert through each side wall—lateral discharge into chamber—would give 100 square feet for each.

Increasing the time of lock operation to 10 minutes would give a value for 'a' in above of 160 square feet, or 80 square feet, for each culvert through side walls.

In comparing the above with the adopted standard for a 30-foot lift lock of the United States Deep Waterways,* we find that in the latter the required time of lock operation is 11·8 minutes by culverts of 94·5 square feet area through each wall; these locks being 740 feet between quoins by 80 feet in the chamber, or 16,950 square feet, more area than the Georgian Bay canal locks.

Taking side wall culverts of the same area as those adopted by the United States Deep Waterways locks—13·5 ft. x 7 ft—would give a time value for the operation of a lock of 30-foot lift of 8 minutes 28 seconds.

Any increase in time of lock operation over 8 minutes decreases the velocity at the mean section of approach mentioned above, which is as previously shown for the above time, not of a serious nature.

Wall culverts necessitate very particular design of the main walls for the valve accommodation, &c., and the carried strains entailed thereby, and require greater base width than a solid wall; and if the culvert area is less than 13·5 feet by 7 feet, the time of lock operation would be correspondingly greater than 8 minutes 28 seconds.

Floor culverts drawing their supply from a well immediately above the lift wall, and discharging under the lower gates are designed without trouble for the total culvert area of 200 square feet necessary to operate the lock in 8 minutes and as shown on the general plan of the single locks.

This system requires excavation for trench to seat the culverts below the elevation of the lower sill and throughout the chamber, and a system of flooring with vertical openings connecting chamber and culverts in a manner similar to that at present in use in many locks.

STANDARD SINGLE LOCKS.

With the exception of the Dalles lock at the Georgian Bay level, the location of all single locks throughout the district will be within rock excavation; the surface of the rock being in all cases at a considerable distance above the elevation of the floor of the chamber. In order to take advantage of this condition as far as possible in securing the least excavation to seat the side walls of the structure, the single locks were designed for operation by culverts under the chamber floor.

This allows a large proportion of the side walls, from the floor level to the rock surface above, to be of a small uniform thickness, say 6 or 8 feet; the rock side walls of the lock pit excavation, with this concrete veneer as it were, forming much of what would be the side walls of the chamber were those walls seated at grade. This will prove a considerable economy in many cases as the single lock structure will have a length of 896 feet over all.

Concrete cut-off walls will join the approach walls of the lock above and below with the adjacent limit of excavation to prevent undue saturation of the backing.

The face of the side walls of the lock are plumb throughout, except at the coping, where they are set back 1 foot on a batter above the water surface to prevent fracture. The coping width of the approach walls above and below is 10 feet, the width of the chamber wall 6 feet. The back of these walls, below the frost batter will be stepped to the economical section consistent with existing strains and the adopted factors of safety; the width of base above the uniform section lining the lockpit excavation depending upon the elevation of the rock surface.

Stairways in reinforced concrete join the lower walls of the lock on both sides; snub hooks in the face of the chamber wall, midway on the lift, will facilitate lockage, and ladders within the gate recesses will give access to the chamber from the coping.

The factor of safety against overturn by the backing, approaches 3·0, that against sliding 2·5 with a co-efficient of friction of 0·6.

* Report of the U. S. Board of Engineers on Deep Waterways, 1900.

The recess walls are of uniform rectangular section; at the upper gates they are 24 feet in width by 22 in height or more, dependent upon the elevation of the rock surface.

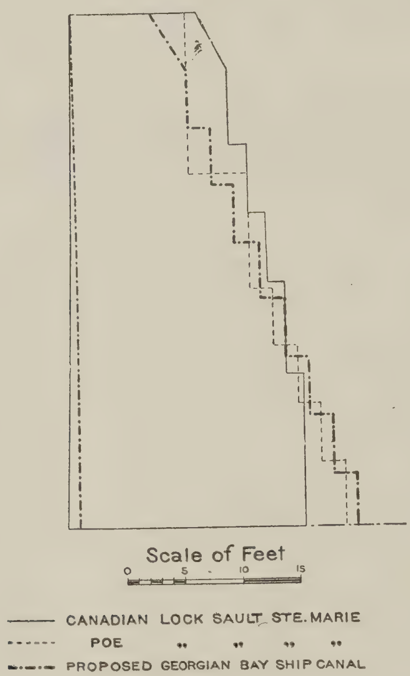
At the lower gates they are 29 feet in width by a height from sill to coping varying with the lift. They are calculated, with the backing, to withstand the hydrostatic pressure plus the gate thrust, with the same factors of safety.

In no case does the resultant line of pressure fall without the middle third of the base; compression in the walls will not exceed 10 tons to the square foot, and tension is eliminated.

The weight of concrete in the calculations was taken at 140 pounds and the backing at 110 pounds to the cubic foot.

A graphic comparison may be made here of the side walls of the Nipissing district locks with those of the 'Soo' locks, Canadian and American, all inclosing a chamber designed to accommodate vessels of like size. The cost per cubic yard of the Georgian Bay locks as designed would be less than one-third that of their prototypes at the 'Soo.'

PLATE D.



The lift wall which spans the lock at the upper end of the chamber will have a thickness on centre line of lock of 20 feet, and a height above the chamber floor the same as the lift. It will carry the sills of the upper main gates with its coping at the same elevation as that of the upper reach; its lower face will form a circular arch of 49 feet radius.

Above the lift wall and below the breast wall will be situated the intake well from which the operating culverts will draw their supply. This well will extend the full width of lock by 28 feet in length at its floor level, the bottom of the well being four feet below the floor of the culverts, forming a sump. An iron grating will

span the intake well above the level of the roof of the entrance culverts to prevent debris of large size from fouling the valves or entering the culverts.

The breast wall carries the sills of the upper guard gates, 54 feet above the upper main gates; its face in the well will be sloped and form an arch to the same radius as the lift wall.

The sills of the lower main and auxiliary gates are 54 feet apart in line of lock, with those of the lower guard gates 40 feet below the latter. Their sills are set six inches below the elevation of their adjacent floor for protection and are formed of 18-inch by 18-inch oak timber securely bolted to 'I' beams placed well below them in the concrete.

The entrance floors of the lock above and below will be level and stand at the same elevation as the grade of the reach they terminate.

The floor of the chamber is an inverted arch of 265 feet radius, the springing line being at the same elevation as the lower reach, or lower floor, with the inverted apex 2 feet below. This allows 4 feet excess draft in the chamber, much to be desired by vessels of the maximum cross-section for the project as designed, to pass into and out of the lock when at its lowest level.

The lock floor will have a thickness of one foot in the middle, reinforced, and increasing withal towards the sides, and is designed to be sufficiently strong, treated as an arch, to withstand double the upward thrust from the culverts below with the full head.

The culverts by which the chamber of the single lock will be filled and emptied during the process of locking, with the exception of the Dalles lock before mentioned, will be four in number, situated under the lock floor and parallel to it. They will extend from the intake well above the lift wall at the upper main gates to a discharge well below the lower auxiliary, and above the lower guard gates. They are rectangular in section and separated from each other throughout by solid concrete walls, two feet or more in thickness.. Their size will vary with the lift of the lock, as their combined area is calculated to effect the change of level in the chamber in about eight minutes. Circular openings from the culverts through the lock floor give the requisite connection with the chamber; these will have a diameter of 2½ feet, spaced about 30 feet apart, and extend from the lift wall to the recess of the lower main gates. Their total area will have an excess of 100 per cent over the total culvert area.

The floor of the culverts for a sufficient distance in length of chamber below the lift wall, dependent upon the material in excavation, are designed of sufficient strength, treated as a beam, to withstand the full head engendered by the unwatering of the lock for repairs; or when laying the lock dry to the elevation of the culvert floors.

The culverts will be controlled at either end by Butterfly valves turning on vertical shafts, or by roller-bearing valves on tracks sliding horizontally, operated in pairs, and opened or closed by horizontal and vertical connecting rods passing through alley and well, under and up through the lock walls, to the coping; the changes of direction being effected by rocker arms.

An electrically driven worm-gear actuating the vertical rod at the coping level will supply the power, the motor, train and gear being housed over the well containing the vertical rod 25 feet back from face of wall. The valves may be independently operated by hand if necessary.

The valves of the North Bay lock which is of the same standard type, are designed on the roller-bearing type—the 'Coffin' valve—sliding to a wedged seat all around thereby insuring a tight joint at each valve; no undue leakage around the operating valves controlling the summit level being paramount.

The valves in all single locks will be of simple design, built up of steel members and steel sheeted on all sides. They will rest against vertical frames of the same

construction which carry the bearings and are securely bolted into the concrete of the roof, walls, and floor of the culvert.

The areas of the culverts just below the entrance valves and above the discharge valves, increase to slightly larger size so that when the valves are open the total area of entrance and discharge will be the same as that of the total culvert area under the lock floor.

It will be noticed that in the submitted design for single locks the lower valves controlling the outflow of the chamber are below the lower auxiliary gates, and also that the lock discharges through the floor culverts instead of through a well above the lower main gates, the design common to all three of the present ship locks at the 'Soo.'

The use of the well to take care of the discharge from the chamber is akin to the old system of discharging by valves through the gates themselves, and portends to an undesirable current. This creates a strong tendency to movement in the direction of the lower gates by boats locking down, requiring them to be very securely held by their cables to the wall bollards, to prevent their surging in that direction—perhaps disastrously to the lower lock gates, were the lower valves opened wide to the full head.

With the system designed there would be no current in the chamber consequent upon lockage, the volume of discharge would pass through the floor to the operating culverts beneath and out through their discharge well below the lower auxiliary gates.

The lock will be fitted with 5 pairs of steel gates, upper guard, upper main, lower main, lower auxiliary, and lower guard. The upper main gates and the guard gates above and below will be of the same size for all locks—37½ feet long by 24 feet high. The leaves of the lower main and lower auxiliary pairs are similar in all dimensions with regard to each other, their width will also be 37½ feet and their height will vary with the lift.

The gates will be built up of horizontal steel members and steel sheeted on the up-stream side; oak miter and heel posts throughout their height being firmly fitted thereto. They will rest upon pivot-bearings under the heel post and be held to their seat along the quoin by an adjustable collar at the top of the heel post immediately below the coping level which in turn is attached to an anchorage let into the concrete; they will swing through an arc of about 68 degrees.

The gate recesses are 39 feet long and 5 feet in depth of wall, tapering at each end, and are so arranged that when the gates are open their lower face will rest entirely within the line of wall.

These gates were designed and estimated for by Mr. Henry Goldmark, C.E., of Montreal, and a detailed description of them will be found in Appendix C.

They will be operated by 'I' beams, attached to the top of the gate about two-thirds out from the quoins, which move in and out of recesses checked in the coping to receive them as the gates open and close.

The beams are actuated by rack and pinion—the rack bolted to the web of the beam—electrically-driven through train gear; the motors and machinery being contained below the coping level. Like the valves they can be independenty operated by hand, if necessary.

LOCKS WITH RIVER WALLS.

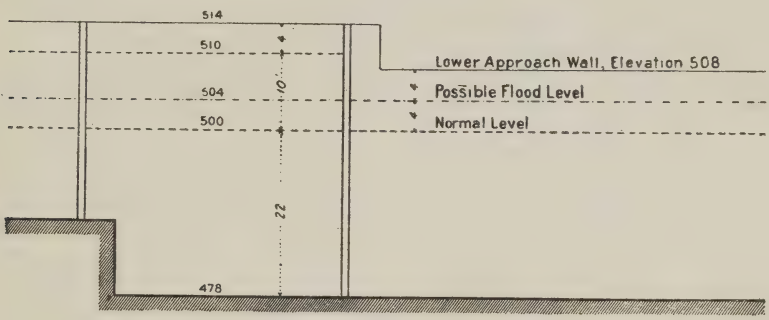
The north wall of the Deux Rivières lock and the walls of the Dalles lock are of stronger and different design than that followed for the walls of the other single locks. The former will be subjected to the full head of the upper pool on the river side besides stone backing laid to a pitched slope some distance behind it. The west wall of the Dalles lock will have no backing and the east wall will have to bear pressure of saturated material when the lock is unwatered.

NIPISSING DISTRICT.

Single Locks.

Location.	Water Surface Elevations.		Floor Elevations.		Lift.	Depth on Floor.		Height of Chamber Wall.	Elev. Coping.
	Upper.	Lower.	Upper.	Lower.		Upper.	Lower.		
Dalles	600	580	578	556	20+	22	24	48	604
Five Mile	624	600	602	578	24	22	22	50	628
Chaudiere	648	624	626	602	24	22	22	50	652
Trout Lake	677	648	651	626	29	26	22	55	681
Les Epines	557	540	535	518	17	22	22	43	561
Plain Chant	540	510	518	488	30	22	22	56	544
Mattawa	510	500	488	478	10	22	26*	36	514
Deux Rivieres	500	470	478	448	30	22	22	56	504

* Reference to W.S. Ottawa backing up from Deux Rivieres.



MATTAWA LOCK

LOCKS IN FLIGHT.

Locks in flight occur at three places in the Nipissing district, one at the Rocher Capitaine and the other two in the divide separating Deep river of the Mattawa waters from Talon lake 3 miles directly above. At these localities an extreme lift is necessary to accomplish the most economic project of the raised water surfaces of the adjacent pools. Single locks would call for too large proportions to be considered. Each flight sits well within excavation in solid rock for its entire length, and the locations are admirable for the purpose.

The chamber dimensions are identical with those of the single locks and they may be described as two single locks joined together. The upper gates of the lower lock being the lower gates of the upper lock, in this case the intermediate gates of the flight.

A departure from the operating system of the single locks is made necessary in regard to the locks in flight consequent upon the great head of 60 feet which will prevail between the upper and the lower chambers during lockage. On account of the excessive strains to which the lower lock floor and the controlling valves between the upper and lower locks will be submitted, were floor culverts employed, it was judged that a more conservative design with adequate control would be obtained by wall culverts having lateral openings into the chamber, with that control by circular cup valves; the efficiency of which have been proved in practice. To this end the locks in flight were designed substantially as shown by plate 18. The upper lock takes its supply from a well above the lift wall situated similarly to those of the single locks,

and discharges through lateral openings circular in form, from the wall culverts into the upper chamber; thence (in the process of emptying the upper into the lower chamber) back into the upper lock culverts and down through vertical wells to the lower lock culverts, from which similar lateral openings to the lower chamber effect the change of level between the two locks. The discharge of the lower lock is accomplished in a similar manner, the culverts themselves opening into a well below the lower auxiliary gates.

The culvert area is 8 feet x 12 feet, or 192 square feet for both, which will effect the total change of level from the upper to the lower pool, or vice versa, in 14 min. 12 sec.; all flights overcoming the same difference of level, sixty feet. The lateral openings have 60 per cent excess area over that of the culverts.

The position of the operating culvert is well within the wall, being 10 feet back from its face. The side walls throughout are designed with the same stability as those of the single locks, the difference in pressure caused by the difference of head in the culverts, supplying an additional condition in the calculations.

The system of operation by wall culverts demands that the concrete side walls be of uniform section from coping to grade of floor, and thus lose the natural advantage in seating the structure within the solid rock where a large volume of the side wall could be dispensed with as in the case of the single locks.

The Upper Paresseux flight will have a lift of 60 feet with the summit storage level at its highest elevation 677, and a lift of 56 feet at the lowest estimated level, elevation 673, the depth on the floors of these 2 locks being 22 feet in the latter instance.

The control of the wall culverts will be by vertically operating balanced cylindrical valves, something in the nature of an inverted tea cup, covering a vertical well which joins the horizontal culverts in the lock walls above and below, the difference in pressure between the two pools being ingeniously contrived to make the valves automatic in action. They are suspended by chains passing over sprocket wheels at the coping level to counter weights, the suspension shafts of which would be actuated, in the event of accident, to the pilot valve controlling the automatic action, through electrically driven train gear, and could also be raised and lowered by hand. The control of the automatic device is effected through light train gear driven by very small motor.

A description of the automatic valve appears under next heading.

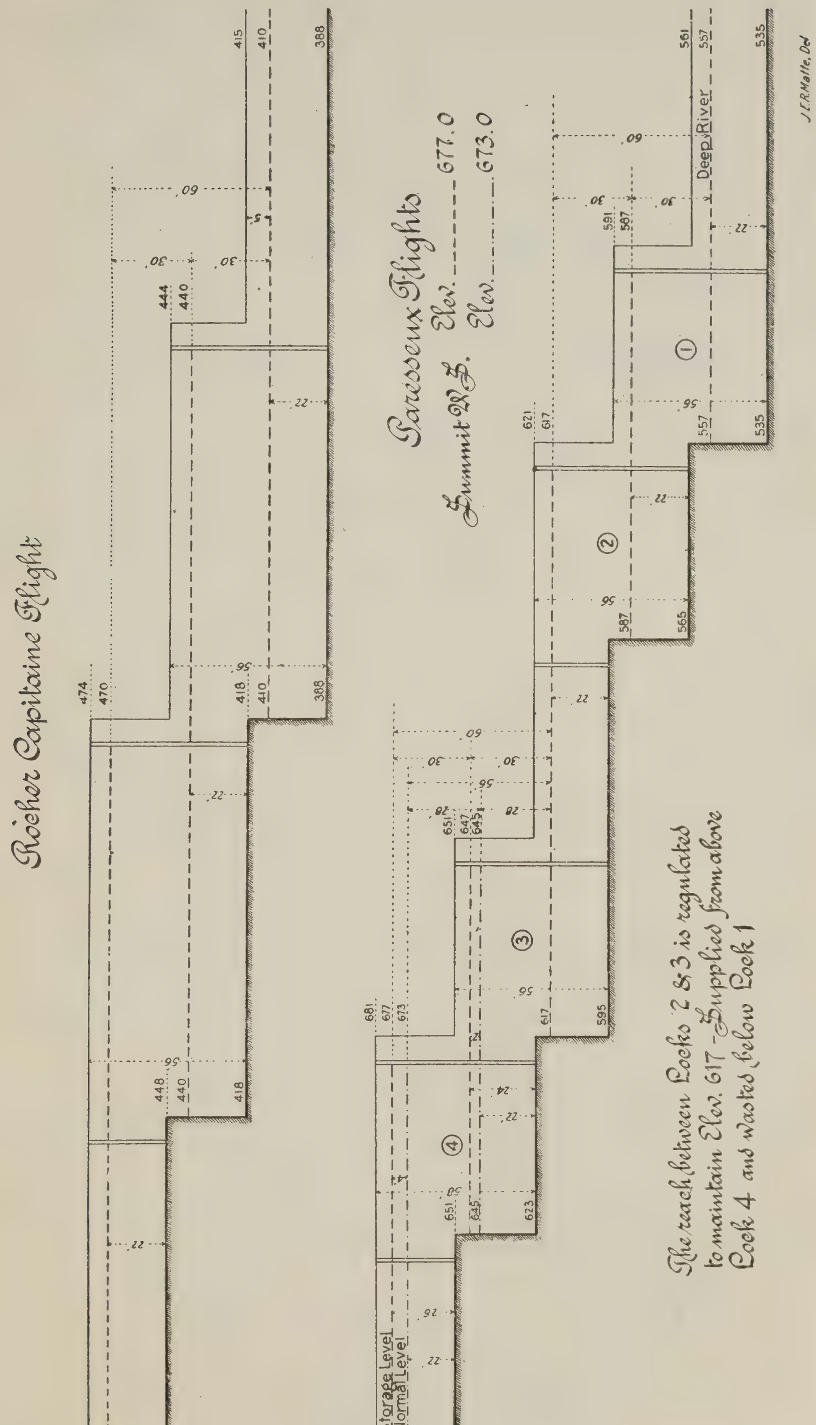
Each flight will have 7 pairs of lock gates, upper guard, upper main, intermediate main, intermediate auxiliary, lower main, lower auxiliary, and lower guard. The upper main gates and the guard gates will be of the same size and design throughout as those of the single locks. The intermediate and lower gates will bear the some relation to the lower gates of a single lock with 30-foot lift. Their operation will be the same as that described for the single locks.

NIPISSING DISTRICT.

Flight Locks.

Location.	Water Surface Elevations.		Floor Elevations.			Lift.		Depth on Floor.			Height of Chamber Wall.		Elev. Coping.	
	U.	L.	U.	I.	L.	U.	L.	U.	I.	L.	U.	L.	U.	L.
Upper Paresseux.....	677	617	651	623	595	30	30	26*	24*	22	58	56	681	651
Lower Paresseux.....	617	557	595	565	535	30	30	22	22	22	56	56	621	591
Rocher Capitaine.....	470	410	448	418	388	30	30	22	22	22	56	56	474	444

*To accommodate variation of storage depth in summit.



Rocher Capitaine Flight
Paresseux Flights
Summit W.L. Elev. 677.0
Elev. 673.0
Deep River
Storage Level
Normal Level
The reach between Locks 2 & 3 is regulated to maintain Elev. 617 - Supplied from above Lock 4 and wasted below Lock 1

The size and consequent total area of the operating culverts to effect the change of level in the chamber in eight minutes, or as near as may be without fractional culvert dimensions, is dependent upon the lift, the area of the chamber being uniform.

This is obtained from the derived formula:—

$$a=\frac{2\ A\ \sqrt{h}}{c\ t\ \sqrt{2g}} \text{ for single locks, and } a=\frac{A\ \sqrt{h}}{c\ t\ \sqrt{2g}} \text{ for flights.}$$

Where a = total area of culverts sought,
A = horizontal area of the chamber,
h = lift in feet.
t = time in seconds (480).
c = frictional coef., 0·6.
g = 32·2.

Consequent data with range of time for change of the chamber level and rate of change is set forth in the following table.

Location.	Lift in feet.	Number of Culverts.	Culvert Dimensions. Width.	Culvert Dimensions. Height.	Total Area.	Elapsed Time. M.	Elapsed Time. Sec.	Rise or fall in Feet per Minute.
					Sq. Ft.	M.	Sec.	
			6	8	*96			
All flights	60	2	8	12	†192	16	40	3·6
Deux Rivières	30	4	6	8	192	8	20	3·6
Plain Chant	30	4	6	8	192	8	20	3·6
North Bay	29	4	6	8	192	8	12	3·5
Chaudiere	24	4	6	7·5	180	8	0	3·0
Five Mile	24	4	6	7·5	180	8	0	3·0
Dalles	22	2	8	12	192	7	10	3·0
Les Epines	17	4	6	7	168	7	8	2·4
Mattawa	10	4	6	6	144	6	46	1·5

*Between flights. †Through chamber walls.

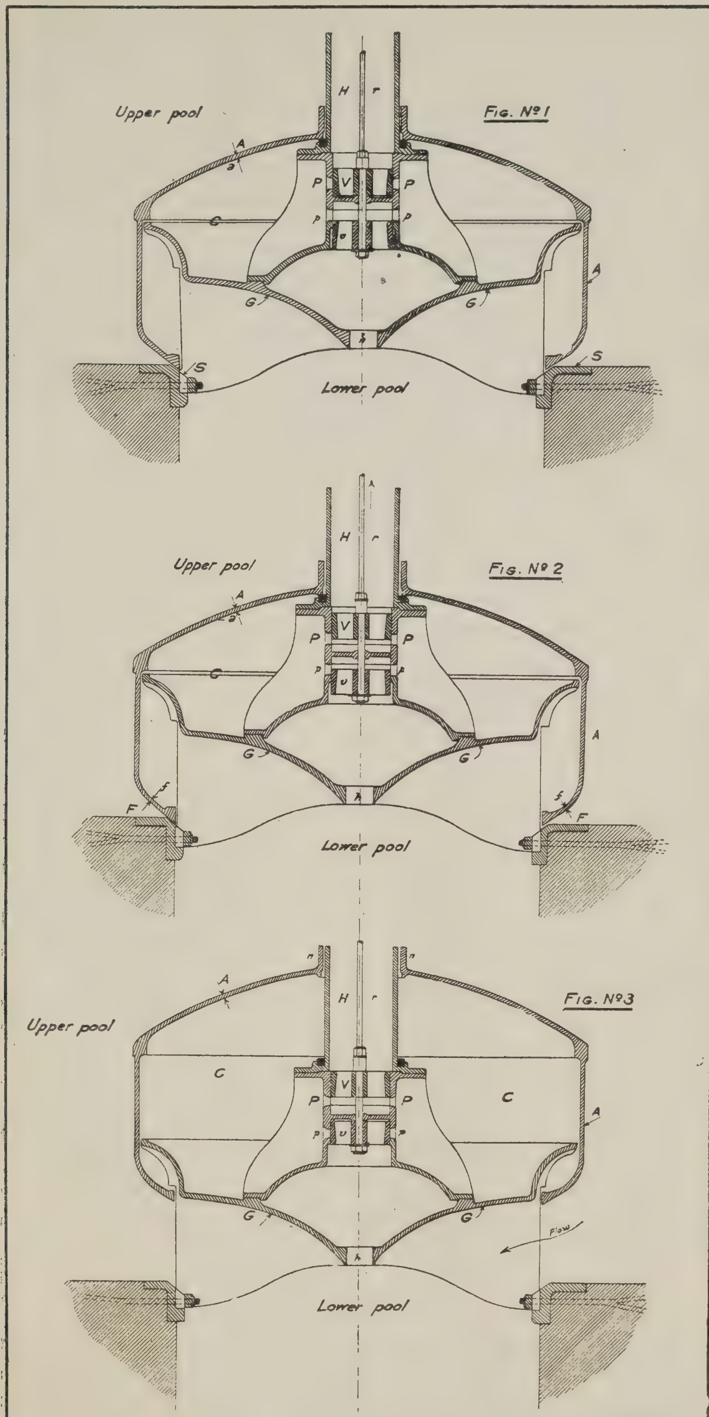
AUTOMATIC VALVES.

The Cluett self-operating, balanced valve for the control of a vertical circular sluiceway when under pressure is the invention of Sanford L. Cluett, C.E., of Hoosick Falls, N.Y.

The valve has been in sucessful operation for some years in controlling the operating sluices of the United States government locks on the improvement of the Big Sandy river, Kentucky, and other places.

This valve is a modification, or rather an improvement, of the 'Fontaine' valve, in use for many years by the French government for the control of the operating culverts of locks on different rivers in France, a description of which is unnecessary here.

The Cluett valve is made self-operating by utilizing the difference of pressure due to the difference of head between the upper and lower pool, and is illustrated briefly by figures 1, 2 and 3.



Cluett Automatic Valve.

See fig. 1.

This shows the valve closed under pressure. The valve consists of four parts: The casing or movable part AA, the fixed part GG, the valve VV, and the valve-seat SS. As will be seen from this plate the pressure on the casing at the point A a, is greater on the outside than on the inside, due to difference of head of the two pools. The pressure on the outside of casing not being allowed to enter the inside of it on account of the valve V closing the ports P P. The pressure on the inside of the casing due to the head of the lower pool being permitted to act through the port H, and the valve V, which leaves the ports p p open. In this condition the excess of pressure on the outside of the casing forces it firmly against the seat S S. It being desired to open the valve in order to permit the water from the upper pool to flow into the lower, the valve v v is raised by means of a hand-screw on the coping connected to the valve-rod r, during which operation the valve will be at some instant, as shown by fig. 2.

It will now be seen that the pressure on both sides of the casing A A in the chamber C are the same, or that due to the upper pool for the reason that that pressure is transmitted through the cylinder H to the inside of the casing C by means of the uncovering of the port P P; the casing A A or the movable part of the sluice-valve is now in a balanced condition in so far as the roof and the vertical sides are concerned.

It will be seen, however, that the lower part of the casing is turned inwards, forming an inverted conical ring F F f f.

In the position at which the valve is shown by this figure the pressure on the outside of this ring F F is due to the difference of head between the upper and lower pools, while that on the inner surface f f is due to the pressure of the lower pool alone, which pressure is not being allowed to enter the chamber C on account of the closing of the ports p p by the valve v.

The vertical component of this difference of pressure tends to raise the casing A A to the position shown in fig. 3.

In the position as shown by the latter plate, and during the flow as indicated by arrow, the pressure inside the casing C remains the same as it is on the outside or that due to the upper pool alone; it being noted that the port P P is now open, whereas the port p p is closed, and the casing upon reaching this position is held there by cable or chain attached to casing A A (connected at N N) and passing over pulleys at the coping to suitable counter weights, the shafts of which pulleys being held by a friction device to prevent the valve from lowering when the upper and lower pools reach a common level.

The weight of the casing submerged is slightly in excess of the counter weights, so that the friction being released when the pools are at a common level the casing drops by gravity to its original position, shown in fig. 1.

It will be noted that during the operation the valve is in a perfectly balanced position regarding difference of pressure. During the flow the guide-plate G G acts as a director of the jet in such a manner as to prevent surging, or in other words, as a sort of 'vena-contractor.' It may be added that during the instant of opening and throughout the travel of the casing vertically, it is aided in that direction by the vertical component of the dynamic head against the inverted conical face of the sluice-valve.

APPROACHES.

The approaches to all locks are lined with heavy timber stone-filled cribwork, all materials for which are in the immediate locality. They are estimated of square section, the width of base being equal to the height, and with oak wailing for their entire length.

Boats in the approaches are supposed to follow the usual rule of the road, passing each other to port. To force this condition and to make the entrance to the lock on as direct a line as possible, the cribwork on that side will be nearly in line with the inside face of the chamber. In plan it will have a splay from a parallel to the centre line of about 1 in 12. This wall will carry snubbing posts as will the shore and bank on that side for a sufficient distance below the crib or berth the boats waiting for the lock.

On the starboard side of vessels passing out of the lock there will be a line of similar cribwork 400 feet long, with a splay, in plan, of 1 in 4, which will permit boats leaving the lock when clear of its walls, to gain the starboard side of the canal quickly. See cut on page 174.

Much inconvenience has been caused at the 'Soo' locks by vessels entering the lock at an angle to the centre line and thereby striking the lower face of one of the gates opened to receive them; the opinion expressed by the engineers in charge of those structures is that a straight approach cribwork to the lock on the starboard side of vessels entering it would remedy that evil, and as far as possible the approaches to the locks of the Nipissing district have been planned with this in view.

In many places where approaches are necessary the depth is too great to permit of cribwork being seated on the natural bottom and at these places stone filling has been estimated for, from the bottom up to grade, the cribwork being seated thereon.

MIDDLE GATES.

An additional set of lock gates placed midway in the chamber, of the same size, and resting against sills at the same elevation as the lower main gates, has been considered in connection with the locks as a means to further the despatch of vessels of smaller size locking up or down, and furthermore to conserve, in the Summit locks, the amount of water required for lockage.

Regarding time saved in lockage their use does not warrant their incorporation in any of the lock structures, and the estimate would be largely increased thereby, necessitating an extra set of gates and an extra set of valves at each lock.

A saving in water required for lockage might be expected from them if installed midway in the chambers of the Summit locks; the saving there would be small and practically non-effective, considering the total season lockage. Locks with gates of this nature are in use at present on the St. Lawrence system, but only to facilitate the passage of consorts in tow by making one lockage for all, a condition not likely to be met with on the projected Georgian Bay canal system where speed of delivery and consequent time of transit is essential.

Freight in tow is becoming obsolete on the Great Lakes, the money invested in a carrier compels her to make the most trips between terminals during the open season. Experience has proved that a power carrier with consorts is a losing proposition as compared with carriers with independent power on account of delay consequent upon waiting for each other to load or unload at terminals.

UNWATERING.

The locks of the Nipissing district are designed with a view to their being completely unwatered, and to this end a pumping plant carrying electrically-driven centrifugal pumps built in the lower walls of each individual lock has been estimated for and included in the cost of electrical equipment. The intake will be from the culvert discharge well below the lower auxiliary gates, and the discharge a short distance below the guard gates.

The controlling valves with their operating machinery below water and the lock-gates are such as not to require renewal or repair to any extent, as they are of simple and heavy design, but in view of such being necessary, together with repairs to the

face of the walls, floors, sills, culverts and the frames of the operating valves, and cleaning the sump well, the locks will probably be unwatered prior to the beginning of a season of navigation.

To unwater all the fights will only require two pumping plants, one at the lower walls of the Rocher Capitaine flight, the other at the lower walls of the lower Paresseux flight, each being the same size as those designed for the single locks and sufficient to unwater the chamber of the lower lock in from 12 to 14 hours.

The Upper Paresseux flight, the basin below it, and the upper lock of the Lower Paresseux flight may all be unwatered by gravity; the lower chamber of the lower flight only requiring to be unwatered by pumping should it become necessary. The economic value of this location with regard to the above should not be lost sight of.

OPERATION.

Power to operate the lock gates and valves, and to light each lock and approaches thereto, will be obtained, with one exception, from a hydraulic driven electric plant nearby, generally adjacent to the dam which confines the reach above.

Two separate independent units, each of the same capacity, will form the power development at each location from which the distribution is made to the controlling and operating stations.

The fall or head of water engendered by the dam at each location is utilized to drive duplicate turbine sets, each direct connected to D.C. generators which are used to charge storage batteries of the Cloride type. These storage batteries are of a sufficient capacity to operate the motors of the gates and valves of each lock for 36 lockages during 24 hours, and also furnish power to the light circuits during 48 consecutive hours without re-charging. Each generating set is independent, and arranged to furnish the power necessary for operating the lock without discharging into the accumulators, thus affording a safeguard against delay through injury or during repair to either set.

The turbines are small and in no case will those of either set be required to develope over 50 H.P. at any time, and then only during a short interval consequent to a re-charging of the accumulators which might be necessary after a shut down of the generating plant for repairs, or to feed the light circuits under similar conditions.

The operation of the lock is controlled from two operating cabins, one at each end of the lock; they are set back from the coping and overlook the upper and lower gates.

The power mains are led to the operating cabins, from which the distribution is controlled by interlocking circuits. This interlocking is arranged in such a manner that the lock must be in the proper condition with respect to the position of the gates and valves before the power may be used from either cabin; one cabin only having power at one time.

The gate and valve machinery may be operated independently by hand in case of failure of the generating systems.

The direct current system at 500 volts was used on account of its ease of operation and control, and the shortness of transmission.

The estimate for the electrical equipment was prepared by Mr. G. F. Chism, Electrical Engineer, who went fully into the requirements at each point. His report in full thereon will be found in appendix D.

The estimates are based upon current practice at the present time.

POWER HOUSES.

Rocher Capitaine.—The power house is adjacent to the lower lock of the flight and about 600 feet from it. The intake is in the approach 1,200 feet above from

which water is conveyed to the wheels through circular steel penstocks; the efficient head being 60 feet. The light circuits extend for 10,300 feet above and 1,000 feet below the flight.

Deux Riviéres.—The power house is in the dam immediately adjacent to the lock, the power being developed from a fall of 30 feet. The light circuits extend 7,800 feet above and 1,200 feet below the lock.

Mattawa lock and Plain Chant lock.—One power house supplies both locks, it is situated in the Plain Chant dam adjacent to the lock there and developes power from a fall of 30 feet. A transmission line 11,800 feet long supplies the power to the Mattawa lock. The light circuit extends from 1,300 feet below the Mattawa lock to 2,000 feet above the Plain Chant lock and serves to light the reach, 10,600 feet long between the two locks together with the approaches to each lock therein.

Les Epines.—The power house here is in the dam adjacent to the lock; the development being from a 17 foot head. The light circuits extend from 2,600 feet below the lock to 3,800 feet above.

Paresseux flights and canal.—The power house here is on the shore of the river at the turn below the Paresseux falls and some 500 feet from the upper lock of the lower flight. The intake is in the upper approach to the lower flight and delivers water through circular steel penstocks to the power house 450 feet lower down, the head being 60 feet. Transmission lines 6,600 feet long supply the power for the upper Paresseux flight, the light circuits extend from 4,400 feet below the power house to 13,400 feet above, lighting the basin between the two locks and the canal from the upper flight to Talon lake.

North Bay lock.—The power is developed here by gas-producer plant in order to conserve water out of the Summit reach that might otherwise be used in power development. The power house will be adjacent to the lock and will supply power to operate the lock, a single leaf bascule road bridge across the lock, and a double track double leaf railway bridge 2,000 feet below. The light circuits extend from Trout lake through the cuttings to the lock and along the canal below to the entrance cribs in lake Nipissing, 23,900 feet in all.

Chaudiere lock.—Power house for this locality is at the dam site in the main river 1,200 feet from the lock. The developed head is 24 feet the light circuits extend 3,200 feet above to 8,000 feet below.

Five Mile.—The power house here will be at the foot of the rock fill dam about 800 feet distant from the lock. The fall developed is 24 feet; the light circuits extend from 1,200 feet above the lock to 7,800 feet below.

Dalles lock.—The fall at the Dalles lock will average 21 feet and the power house itself will form a part of the rock and overflow dam on the west. The light circuits will extend 4,400 feet above the lock and 10,400 feet below, lighting that approach to the lock where the river widens to meet the lake.

The hydraulic plants were estimated individually or for each location and were complete in every respect; the power houses were estimated to be of steel concrete construction, and of suitable space for the power plant only to be contained therein.

LOGS.

The route if completed for the traffic designed may not be used for the passage of free logs as at present.

Nor may rafted timber be passed through successive pools; this is absolute, and will be conceded by all technical minds conversant with the problems of restricted

navigation for the large lake-carrier and the nature of the route to be developed.

The former would institute a menace to which no master would subject his vessel and the latter is too uncertain of complete control within the numerous submerged and other artificial channels that are necessary to the project.

The Ottawa river above the Des Joachims, the Mattawa river from the summit lakes down, and the French river from Lake Nipissing to its mouth, are largely used at the present time to pass the logs of the winters' cut during the spring floods, and also later during the season when the upper levels may be conserved by existing dams and opened for the purpose of later drives.

This system will require to be replaced by one which will allow the logs to be cut into marketable lumber at points adjacent to the canal route—at the mouths of tributary streams which now form the lines of communication from the timber limits to main rivers mentioned above—instead of at the large centres of the lumber interests as they exist at the present time.

Lumber shipment by barges from the new points of manufacture may then be made and save the river route to the canal for the purpose designed.

The waters of the Summit lakes must assuredly be conserved for canal purposes only and for obvious reasons. In the event of the construction of the Amable du Fond feeder canal, the lakes now forming the catch basins of the Amable du Fond river watershed may not be used as at present for storage to force the spring drives of that river; but only for storage to supply the Summit level, else the usefulness of the feeder canal would be largely a question of doubt.

The lumber mills at present situated on the shores of Lake Nipissing; Wisawasa, Callender, Sturgeon Falls and Cache Bay would suffer no other inconvenience than that of having to contend with a higher lake level by about 5 feet than has been. Their source of supply comes mainly by the rivers adjacent to their locality and will afford no danger to the canal route.

The above opens up a very broad question and one which will undoubtedly require an exhaustive investigation as to ways and means of preserving invested interests without disturbing the ultimate object of the project.

S. J. CHAPLEAU, C.E.

SUMMIT LEVEL.

SUMMIT REQUIREMENTS.

The Summit level of the proposed waterway extends from Lake Nipissing to the head of the Mattawa river, embracing Trout lake, the Little Mattawan river, Turtle and Talon lakes, a distance of about 25 miles.

The height of land proper separating the waters of the Great Lakes and those of the Ottawa river, occurs between Lake Nipissing and Trout lake, the latter being the highest body of water on the route. The granite ridge forming the divide in many places is very little above the waters of Trout lake, thus affording several possible locations for the canal which required investigation.

The respective elevations of the summit lakes above mean sea level are:

	Feet.
Lake Nipissing, mean level	640
Trout lake, mean level	663
Turtle lake, mean level	662
Talon lake, mean level	635

For purposes of comparison, the elevations of both ends of the proposed route, referred to the same datum, may be given here:

St. Lawrence river, at Montreal; low water, 18 feet.

Georgian Bay, Lake Huron; low water, 578 feet.

The maximum range of fluctuation of the lakes at the Summit is from five to eight feet. The drainage area tributary to Trout, Turtle and Talon lakes, is 342 square miles as delineated on plate 31, and that of Lake Nipissing 4,077 square miles.

In deciding on the Summit level of the waterway two alternatives offered themselves:

1st. The formation of a Summit level above that of Lake Nipissing, with Trout, Turtle and Talon lakes.

2nd. The lowering of the above-mentioned lakes to the level of Lake Nipissing, thus including that body of water in the Summit reach.

The first proposition was dependent entirely on the amount of water available for canal purposes; and though, without doubt, at first sight the more economical, without adequate water supply, it would have to be rejected.

The second proposition gave at once assurance of ample water supply, much above the requirements, but the additional cost might be almost prohibitive, with the serious objection of a much longer time being required for construction.

These conditions necessitated the most careful investigation, and deductions especially in regard to amount of water available, had to be based on reliable information and facts.

A special hydraulic party was therefore formed to collect the necessary data at the Summit, and during two years the most exhaustive sets of measurements and observations were made.

In all preliminary investigations, which were made previous to this survey, no systematic study of the conditions of the Summit watershed appear to have been made.

It was arbitrarily assumed that it was impossible to maintain a Summit level that would not embrace Lake Nipissing, owing to a belief in the scarcity of the water supply

of those lakes which naturally formed the Summit, and of which advantage is taken in the present project.

On account of a lack of proper data, the topographic value and possibilities as a storage reservoir of the basin lying west of the Talon chute, when the water level within is raised to its limit, was not considered by former investigators.

It must be stated, however, that in the early surveys of 1855 and 1857, by Messrs. Shanly and Clarke, conditions were very different from those of to-day in regard to Lake Nipissing.

Mr. Shanly, in his report, dismisses the question of a Trout Lake Summit by simply stating that the water supply is inadequate, and proposes to raise Lake Nipissing about 16 feet, and lower Trout lake to meet this level, thus including Nipissing in the Summit reach. This was probably the proper solution at the time, on account of the land around the lake being practically unoccupied, and undoubtedly was one of the reasons why proper attention was not given to the study of the higher basin.

The shores of Lake Nipissing are so low that the raise of level proposed would naturally flood large tracts of land.

At present such a scheme is inadmissible. The number of settlements, villages and towns, apart from railway interests which would be affected are vital objections to it.

It has been ascertained that the highest point to which Lake Nipissing could now be raised and maintained, without affecting too many interests, is at about elevation 648, or 8 feet above ordinary low water level, and from two to three feet above the highest flood water.

At that stage even, large areas of land would be affected, but the benefits to navigation on the lake would more than compensate the damage caused by flooding the low lands.

Elevation 648 would therefore be the governing level, should Lake Nipissing be selected as the Summit, and all cuts through the height of land to the foot of Talon chute would have to be excavated 22 feet below that level or to elevation 826.

From the preliminary investigations made, it was at once evident that for a large canal, requiring widths of 200 to 300 feet, this would involve the removal of enormous quantities of material, the largest proportion of which would be granite rock of the gneiss variety.

The consideration of the higher chain of lakes to form the Summit was, therefore, imperative.

A thorough exploration of the basin showed that the higher reach would be possible only on condition that the whole of the inflow of water could be controlled and conserved for canal purposes, and further, that an additional source of supply could be obtained in case of a very large traffic developing through the waterway.

The physical features of the country were found to be favourable to both these conditions, and the economic height to which the summit lakes could be raised and maintained to a common level, from the comparative standpoint of conservation of water, cost of the lock structures at either end and permissible lift, minimum amount of excavation, &c., was fixed at elevation 677, lake Talon being raised about 42 feet, and Trout and Turtle lakes about 14 feet above their present level.

This formed a summit basin 22.4 square miles in area, which had to be permitted to oscillate between certain limits in order to use part of the storage water during months of deficient inflow.

The hydraulic investigations showed that this basin would always refill during winter and spring time, even for the years of minimum precipitation, should it be lowered from 7 to 8 feet during navigation season.

In order, however, to make this condition absolutely safe, the maximum oscillation permissible below elevation 677 was fixed at 6 feet, thereby establishing the sill

levels for the locks at either end, and the grade for all cuts within the Summit at elevation 651. This is 25 feet above the formation level of a Lake Nipissing summit cut, involving a reduction of several million cubic yards of granite rock excavation.

In addition to the storage area mentioned, must be added that of Lake Nasbonsing, which is about 148 feet above the level of Talon lake, draining into it by the Kai-bus-kong creek. With control of its outlet at Bonfield a storage of 6 feet will also be available there, over its area of 6.54 square miles.

This can be further augmented by the waters of the Wisawasa lake which could be drained into Lake Nasbonsing.

The principal source of extra supply, however, should the development of the traffic demand it, will be from the Amable du Fond watershed.

This watershed covers about 300 square miles and contains a number of large lakes. The Amable du Fond now discharges into the Mattawa river below Talon chute, and surveys have shown that the river could be diverted to the head-waters of Sparks creek, which flows into Talon lake. By using the lakes at the head as storage reservoirs it would be possible to obtain 700 cubic feet of water per second to augment the Summit supply during the period of deficiency.

(Refer to hydraulic engineer's report and Plates Nos. 28, 29, 31).

The complete investigations made have therefore permitted deductions which may be summarized as follows:

1st. It would no doubt be desirable to establish a Summit which would include Lake Nipissing, as such a body of water within the Summit basin would solve at once the question of water supply for the largest possible traffic through the canal, without recourse to other sources of supply.

But this is not deemed to be advisable.

(*a*) On account of the practical impossibility of raising Lake Nipissing above elevation 648.

(*b*) The cost of a Summit reach at the above mentioned level would be excessive.

(*c*) The time of construction for such a level, would be much longer than for any other reach, and the delay in the opening of the canal would be a serious objection.

2nd. The more economical condition of the project is to establish a storage basin above that of Lake Nipissing, with Trout, Turtle and Talon lakes.

In this case, all the requirements of the canal are met with;

(*a*) By fixing the upper level at the limiting elevation +677 or 29 feet above the raised level of Lake Nipissing, thus requiring only one extra lift of reasonable height.

(*b*) By establishing the lock sills at either end of the basin so as to permit of the water level oscillating from elevation 677 to elevation 671, without interference to navigation, thus creating a storage of 6 feet in a basin 22·4 square miles in area, which is increased by 6 foot storage in Lake Nasbonsing, 6·54 square miles in area, this lake being actually tributary to the Summit waters.

(*c*) With the above mentioned project the total quantity of storage possible, from all sources in the Summit watershed, assuming the worst conditions possible in a year of minimum supply is 5,591,130,309 cubic feet. Assuming that the basin and subsidiary reservoirs are completely empty on the 1st of December, it is shown that they will always fill during the winter and spring months and remain filled until at least June 15 wasting nearly one billion cubic feet of water in the spring, during the lowest year, on account of the limited reserve capacity of the reservoirs.

(*d*) By computation of the daily inflow and storage for minimum years of precipitation, it is found that the summit reservoirs will be empty on November 30 by using 556 cubic feet of water per second.

(*e*) A careful study of the conditions under which all the dams and other structures can be built at the Summit shows that the loss of water by leakage can be

reduced to a minimum, and ample allowance being made for that as shown in the district engineer's report, there will remain available for lockages a minimum of 435 cubic feet per second from the inflow and storage.

(*f*) The amount of tonnage which this supply will pass with the proposed locks and lifts depends on the average size of vessels, using the canal and the frequency of passages. The locks are designed to take the largest freight carriers on the lakes, or in excess of 12,000 tons of cargo per lockage. The Canadian and Poe locks at Sault Ste. Marie have averaged from 1,355 to over 4,000 tons per lockage for the last five years. With the constantly increasing size of lake freighters, it seems reasonable to assume that the type of through vessel which would use the canal would average from 2,000 to 3,000 tons and better.

In regard to the time interval between successive lockages, the passages at the Sault Ste. Marie locks are the best guide possible, being under the conditions of the largest lock traffic in the world, and although the present facilities are already considered inadequate to handle the increased traffic expeditiously, up to the present time, the greatest number of lockages for each lock in a day, and the consequent intervals are as follows:—

Canadian lock—Number of lockages, 34; interval, 42 min.
Poe lock—Number of lockages, 35; interval, 41 min.
Weitzel lock—Number of lockages, 41; interval, 35 min.

This represents a maximum for a particular day, which of course, is not maintained throughout the navigation season.

It will be fair to show what the average time interval was for the season of 1907, when the traffic amounted to over 58,000,000 tons, much the largest on record.

Poe lock—

Length of navigation season, 233 days.
Lockages, 5,487.
Number of vessels passed, 8,475.
Registered tonnage, 26,160,107.
Freight tonnage, 40,859,145.
Average number of vessels passed per day, 36.
Average number of lockages per day, 24.
Average time interval, 1 hour.

Canadian lock—

Length of navigation season, 238 days.
Lockages, 4,592.
Number of vessels passed, 6,346.
Registered tonnage, 12,086,864.
Freight tonnage, 15,585,368.
Average number of vessels passed per day, 27.
Average number of lockages per day, 19.
Average time interval, 1 hour, 16 minutes.

With locks of the proposed size and lift, it is calculated that the average quantity of water required, based for the entire season on alternate lockages, east and west, will be 1,869,563 cubic feet per passage of the Summit, or 21·63 cubic feet per second day, say 22 cubic feet.

In a minimum year of supply, 435 cubic feet at least are available from inflow and storage as shown.

This represents practically 20 lockages per day, and a time interval of 1 hour, 12 minutes.

From these figures, different estimates can be made showing the tonnage which the available supply of water will pass during a navigation season of 210 days.

Three assumptions may be made which seem fair and reasonable, by assuming that each passage of the Summit will represent an average of either 2,000, 2,500 or 3,000 tons.

This will give the following tonnage:—

2,000 × 20 × 210= 8,400,000 tons.
2,500 × 20 × 210=10,500,000 "
3,000 × 20 × 210=12,600,000 "

It must be remembered that this is based on years of absolute minimum supply, which will rarely occur. A supplementary source of supply in the immediate summit basin not included in the above estimate is from Wisawasa lake, where at least 50 cubic feet per second can be secured for the small expenditure of $20,000. This would represent two additional lockages per day.

Moreover, as the docks proposed are 650 feet in length, the expedient may be resorted to, for the summit locks, of placing intermediate gates, and using a shorter chamber for locking small vessels, thereby saving a large quantity of water.

It is expected that this would increase the number of possible passages to 25.

This would give respectively for the three assumptions made, 10,500,000, 14,375,-000 and 15,750,000 tons.

Whether such traffic could be expected, is impossible to predict, but it can be safely stated that in any event such an enormous amount of traffic would take many years to develop, and that a larger water supply would not be required at once.

The limiting capacity of the waterway may be determined by assuming the time interval between lockages at a minimum, say 45 minutes, representing an average of 32 lockages per day.

With this time interval, the possible tonnage would be 13,440,000, 16,800,000 and 20,060,000 respectively, on a basis of an average per passage, of 2,000, 2,500 and 3,000 tons.

It can be seen that it would require hardly double the quantity of water available in the Summit basin proper to meet the demands of the traffic should the canal be taxed to its full capacity.

As previously shown a convenient outside source to augment the supply is the Amable du Fond watershed where large storage lakes exist, and where an additional 700 cubic feet per second during the period of deficient flow can be obtained by diversion, at a cost of $980,000, thereby meeting all demands of a maximum traffic.

(*g*) One of the main factors in favour of the Trout-Talon lakes Summit is the great reduction in cost as compared with the Lake Nipissing Summit.

The former will cost $10,685,326, the latter $20,312,066, or a difference of $9,626,-740 in favour of the higher reach.

All the data concerning the different factors relating to the Summit, such as the quantity of water available, the distribution of flow throughout the year, possible storage, supplementary sources of supply, &c., will be found in the report by the hydraulic engineer. Also a further discussion of results, and possibilities of traffic will be found in the report by Mr. S. J. Chapleau, engineer for the Nipissing district.

The following diagram shows graphically the condition of the water supply within the Summit watershed, in relation to the amount of traffic passed, assuming an average capacity of 2,500 tons for each vessel locked.

Five curves are shown illustrating the effect on the water supply of passing 2,000,000, 4,000,000, 6,000,000, 8,000,000 and 10,000,000 tons traffic.

The summer of the year 1906 being a remarkably dry season it was assumed that it could safely be taken as presenting minimum conditions, therefore the inflow for

that year and the December preceding were used as a base for the calculations for the diagram.

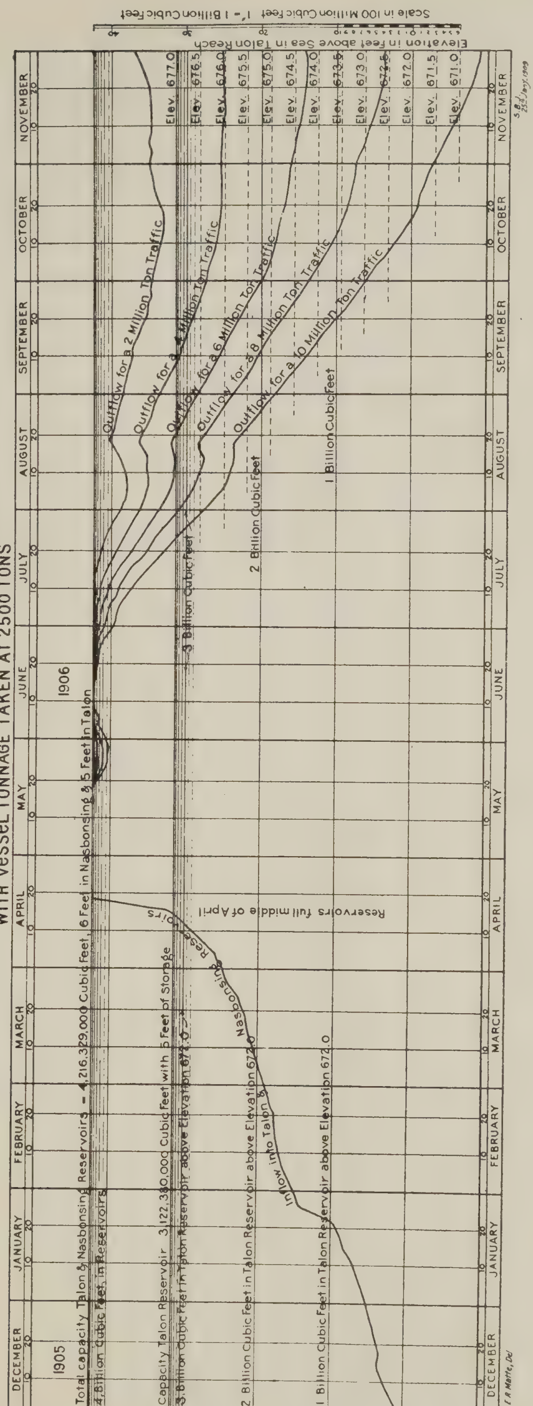
Under these minimum conditions the reservoirs would be empty at the close of navigation (November 30, 1905), then the refilling process begins, continuing at the rate of over 6 hundred million cubic feet per month throughout the winter, until by the middle of April they would be filled.

On May 1st navigation opens, but the inflow continues to be greater than the outflow contingent upon two million-ton traffic as shown by the upper curve in the diagram, until July 6, after this date the inflow, plus the storage in Nasbonsing lake is more than sufficient to keep Talon reach full for the entire season for the stipulated tonnage traffic.

With a ten million-ton traffic the inflow continues to exceed the outflow only up to May 18, when the reservoirs would suffer a diminution, only temporary, however, as the rainfall towards the end of May would replenish them. By June 15 the inflow again decreases and storage would be called upon. With the exception of four days in August when heavy rains caused a temporary rise, this draw on the storage continued until the middle of November when Talon reach was down to elevation 671.

It is seen by the diagram that a traffic of 8 million tons would leave the reach at the close of navigation with over 350 million cubic feet of water in it above elevation 672; thus it is seen that the quantity remaining in the reservoir increases as the tonnage decreases.

CURVES SHOWING THE DAILY INFLOW AT THE SUMMIT DURING THE YEAR 1906, RECORD DRY SEASON;
AND THE DAILY OUTFLOW CAUSED BY A 2-4-6-8 AND 10 MILLION TON TRAFFIC
WITH VESSEL TONNAGE TAKEN AT 2500 TONS



DETAILED REPORT BY MR. ALEXANDER McDOUGALL, M. Can. Soc., C.E.

Section 1.—Summit Water Supply.

Section 2.—Summit Water Requirements.

SUMMIT WATER SUPPLY.

The Georgian Bay canal ascends the French river from the Georgian Bay to Lake Nipissing, and from Lake Nipissing into Trout lake. Trout lake is the head of the Mattawa river and is the Summit of the proposed canal. The canal follows the course of the Mattawa river, which empties into the Ottawa at Mattawa, thence via the Ottawa to Montreal.

Plate No. 31 shows the watershed of the Mattawa river and the general features of the Summit.

Plates Nos. 13 and 14 show the general elevations along this part of the canal route. Trout lake is, ordinarily, about 23 feet above, and Turtle lake about 22 feet above Lake Nipissing, and Talon lake about five feet below it, the corresponding elevations being Lake Nipissing, 640; Trout lake, 663; Turtle lake, 662, and Talon lake, 635 above sea level. These elevations vary with the fluctuation of the water at the different seasons.

The plans for the canal call for the construction of a dam at Talon chute, creating a Summit level oscillating from elevation 671 to elevation 677 from the Talon chute to the western end of Trout lake. This will form a lake of 22·4 square miles of area. The high water level will be 677 which can be drawn down to 671, if necessary, without interfering with 20 foot navigation. The drainage area tributary to the summit is 342 square miles, as shown on Plate No. 3, which was compiled from the township maps of the Province of Ontario. The areas of Trout lake and Talon lake have been determined by the present surveys. The drainage areas of the various portions of the Summit, and Mattawa river, are as follows:—

DRAINAGE AREAS.

	Sq. miles.
Talon Lake—	
From Talon Narrows, including water-area of open water in water-shed	342·0
Area of open water in water-shed	23·9
Turtle Lake—	
From Whitefish bay, including water area	78·0
Of open water in water-shed	10·3
Area of Trout lake	7·7
Area of Turtle lake	1·2
Lake Nasbonsing—	
From Menard's bridge, including water	71.5
Area of open water in water-shed	7·2
Drainage area from Bonfield, including water	64·7
Area of open water in water-shed	7.2
Drainage area of Depot creek, including water	33·4
Area of open water in water-shed	0·6

	Sq. miles.
North River—	
From Mattawa river, including water	92.2
Area of open water in water-shed	0·5
Amable du Fond River—	
From Eau Claire, including water	433·0
Area of open water in water-shed	36.5
Drainage area from elevation 950, including water	305·2
Area of open water in water-shed	33·0
Mattawa River—	
From Mattawa	880·0
Area of open water in water-shed	61·0
Wisawas—	
From outlet of lake	52.9
Area of open water	2·8

Almost the entire drainage area about the outlet of Lake Talon is heavily wooded. In the vicinity of Bonfield and Rutherglen, and in one or two isolated places, there is some farming, but only to a very limited extent, and probably not more than three per cent of the entire drainage area is cleared. Some of the area not now cultivated might be improved in the future, but most of it is not suitable for cultivation, and it is unlikely that any material change will take place in the character of the water-shed.

When the sufficiency of the water supply at the Summit level of a canal is in question, its correct determination is a most important problem. Sufficient water to meet the demands of navigation must be provided at all times.

The proper determination of the quantity available in a minimum year requires a forecast of future conditions which can only be made with safety when the information at hand is reliable and sufficient.

The amount of water varies each year, and the chief difficulty occurs in the prediction of minimum conditions from the existing records.

For a proper comprehension of the water supply problem, it is necessary to study the causes which produce it. The amount of water available from any particular watershed which is usually known as the 'run-off,' equals rain-fall, minus the evaporation, both variable quantities. This run-off, either naturally, or by artificial methods, must also be so distributed over the year as to meet the demands of navigation.

Rain falling on the earth is divided up into different portions. One portion finds its way directly over the ground to the streams where it appears in the form of 'run-off.' The second portion soaks into the ground where it replenishes the great underground storage which again slowly appears in 'run-off' from springs. A third portion is directly evaporated from the ground or taken up by plant life. Streams are also subject to evaporation from their surface. The 'run-off' therefore depends on the character of the surface, the extent and demands of plant life, the quantity of ground storage, of surface storage and the various physical conditions which affect evaporation, &c. We, therefore, require to consider for the Summit supply these various elements with reference to its watershed.

It is not necessary to know the causes which produce the rain fall or snow fall, but rather the laws which govern its evaporation from year to year and from day to day, and if it is possible to determine from measurements extended over a certain period of time, the law which governs the amount and character of the precipitation.

Binnie, in an article entitled, 'The Mean of Average Annual Rain Fall, and the Fluctuations to which it is subject,' published in 'The Proceedings of the Institute of Civil Engineers,' Volume 109, p. 89, London (1896), presuming that the observations are all properly and regularly made, the author states 'that any good record of thirty-

five years and upward may be accepted within limits, and that a period of fifty years is nearly as good as that of a longer period.' Also that 'the conclusion may be drawn that dependence can be placed on any good record of thirty-five years' duration to give the mean rain fall correct within two per cent of the truth,' and that for shorter periods of five, ten or fifteen years, the probable extreme deviation from the mean would be 15, 8, 5 and 4·75 respectively.

It is, therefore, apparent, that if an absolute forecast of the minimum rain conditions is required, that records over a very extended period of time are necessary. Unless these records are available, great care must be exercised in any attempt to forecast the minimum conditions from the records of a short period.

The second variable on which the 'run-off' depends is evaporation, and it is governed by several conditions. As previously stated, the evaporation varies with the character of the soil, the plant life and the condition of the atmosphere.

It has been the subject of study for many years, but the variables upon which it depends are so complicated and interrelated that the results for any particular watershed can only be applied to another watershed with careful discrimination. Its determination is usually made by measuring the 'run-off' from the watershed and from the difference between this and the rainfall we arrive at the evaporation which covers not only the evaporation from the surface, but also that which is taken up by plant life in all its different forms. If the character of the watershed were changing, such as for instance the clearing off of the forest area by cultivation, it would be necessary to consider it at great length. But it is not possible within the limit of this report to go into the subject fully. When the canal is constructed, the Summit must be so protected as to prevent any material change in these conditions.

For our purposes, it is unnecessary to divide the evaporation into its different elements, but only to determine the 'run-off' which is available for navigation. The usual method of doing this is by extended stream gaugings, and measuring the corresponding rainfall over the same period, the difference between which giving the total amount which has been lost. Allowance must be made for the conditions which exist at the beginning and conclusion of any period of time which is under discussion: that is, there may be more or less rainfall existing in the ground in the shape of ground storage, or in the swamps and lakes and surface of the ground of the watershed, and due allowance must be made for this in the calculation.

Ground storage is described as follows in the Report of the Geological Survey of New Jersey by C. C. Vermuele:—

GROUND STORAGE.

'At the close of the winter and spring rains, the ground is saturated with water to a great depth. A large amount of water is held in storage, and all of that which lies above the level of the bed of a stream within the boundaries of the watershed becomes available to either feed the stream at that point or else to satisfy the demands of plants and evaporation. This great reservoir will feed a certain amount of water to the stream irrespective of the rainfall. If the rainfall is sufficient to supply the evaporation and plant growth, the flow from the ground water will remain constant, because the head which forces it through the rocks and gravels is constant. When the rain is insufficient, the head will be drawn down and the flow will decrease at a certain fixed rate. The draft upon ground storage in this vicinity usually sets in between May 1 and June 1 (*.) Once the draught is fairly established and the water drawn down, unless the rainfall is greater than it usually is from June to August, it is all absorbed by the dry earth and does not reach down far enough to increase the head and con-

*In the Ottawa River Valley, it usually commences about June 15.

stant flow of ground water. What may be called the 'under-run' of a stream, that part which depends upon ground storage may be easily determined by inspection of a continuous diagram of flow. In inspecting such diagrams as those of the rivers of New Jersey accompanying this report, it may be seen that rainfalls which, if occurring in May, or in the autumn after ground water has been replenished, would cause violent floods, have no effect at all upon the stream flow when they occur during the dry months. This difference in effect cannot be described to direct evaporation, for, in case of concentrated rainfall, evaporation has little time to act. It is due to the drawing down of ground water, which leaves a great capacity for absorption of rain by the earth.

In the analysis of recorded stream flow following, it will be found that in extreme cases this stored ground water will be drawn upon by stream flow and evaporation to the extent of the equivalent of nine inches of rain. In some cases it will yield to the streams alone a quantity of water equal to five inches of rainfall. A depletion of six inches by the end of August is not uncommon. This depletion must be made good before the fall rains become available to increase the stream flow. Consequently, we frequently find the autumn stream flow to be very much less than the difference between rainfall and evaporation.

Let us now observe what the effect of the ground storage is upon the stream flow. Take a usual case of a stream whose normal yield is twenty inches for forty inches of rainfall annually, and whose ground storage will yield five inches to the stream. If we begin the year with full ground water and end it with depleted ground water, the yield will be 25 inches for forty inches of rainfall. If we begin with depleted ground water, on the contrary, and end with full, we shall have but fifteen inches yield for forty inches rainfall.

In the first case, we have a yield of 62·5 per cent, and in the second 37·5 per cent of the rainfall. This stored ground water will cause streams to continue to flow for weeks and months, even though rain entirely ceases to fall.

Popularly, this is known as spring-water. It often issues in the form of well sustained visible springs, but a larger amount finds its way out unobserved all along the course of a stream. Portions of the surface which are continually saturated and are known as swamps or marshes.

Wells sunk below its permanent level yield continuous supplies of water, popularly supposed to come from underground streams, or 'veins.'

The actual distance below the surface of the ground to which this reserve supply of water is drawn during droughts, is not everywhere the same, nor will all portions of a water-shed deliver equal amounts of water from the ground.

A coarse gravel will contain more water to each foot of depth and will yield that water much more freely than compact earth or rock. When it is said that a water-shed will yield so many inches of water from ground storage, the average yield is intended. The accompanying sketch shows, generally, the manner in which a valley will yield up its ground-water during a protracted drought when the material is varied, and the phenomena which result therefrom and with which all are familiar.

The capacity for ground storage varies widly on different water-sheds. On steep rocky surfaces, the rain largely runs off. The rock, it is true, holds a large amount of water, but it is held tenaciously and discharged at a low rate. The fact is partially compensated for by the greater difference of level on such a water-shed which cause greater heads to force out the water. A rocky water-shed, as level as the sandy basins of Southern New Jersey which discharge large volumes of ground water, would probably yield a very trifling amount. Fanning gives the following data as to porosity of soils:—

Gravel, consisting of small water worn stones or pebbles, intermixed with grains of sand, has ordinarily 20 to 25 per cent of voids; marl, consisting of

limestone grains clays have innumerable interstices not easily measured but capable of absorbing after thorough drying from 8 to 15 per cent of an equal volume of water.

Water flows with some degree of freedom through sand stones, limestones and chalks, according to their textures, and they are capable of absorbing from 10 to 20 per cent of their equal volume of water.

The primary and secondary formations, according to geological classifications, as for instance granites, serpentines, trappeans, gneisses, mica slates and argillaceous schists, are classed as impervious rocks, as are usually the several strata of pure clays that have been subjected to great superincumbent weight.

The crevices in the impervious rocks, resulting from rupture, may however gather and lead away as natural drains, large volumes of the water of percolation. It must be remembered, however, that nearly all water-sheds on rock formation having a covering of disintegrated rock and drift gravels and sands which furnish a large part of the ground storage. A rock valley filled with drift sands and gravels is admirably adapted to supply large quantities of ground water.

From the above percentages, we find that a depletion of nine inches of ground water will draw down the water table an average distance of from 35 to 45 inches in gravels, from 45 to 90 inches in marls, about 90 inches in clays and from 45 to 90 inches in sandstones, limestones and chalks.

In this connection, it is worth while to remember that many plants project their roots to great depths in the earth. Common clover roots have been followed to a depth of four feet. It follows that vegetation, which must be supplied with water, will draw its supply from very considerable depths when no rain fall is available.

As we shall see from our gaugings, the demands of evaporation and of plant life are inexorable. During the growing months of May, June and July, these demands are usually equal to the rain fall, and often in excess of it. Stream flow is, consequently, entirely dependent upon the ground water, which is also frequently drawn upon by evaporation and plant absorption. No scientific treatment of the yield of streams can neglect this important equalizing reservoir of ground water.'

Surface storage 'is another agent which tends to equalize flow to some extent by carrying over some of the water of the wet season to the early dry months, thereby shortening the period of very small flow in the surface storage. Water is held in natural lakes and swamps and fed out gradually to the stream.'

In addition to these two agents, one of the principal factors of variation in our northern rivers is the precipitation of the winter time in the form of snow which might properly be called surface storage of a particular character. This snow fall which occurs from December 1 to March 20, in the majority of years remains on the surface in the condition in which it falls without augmenting the stream flow, except in case of a thaw in the spring. In certain winters, however, thaws occur during the winter with rain fall, increasing the flow of the rivers at that time.

Arrangements were made at the beginning of the survey to measure the various elements which determine the available water supply, and to collect all other possible data which would have any effect on the investigation. It was at once apparent that under natural conditions, without any storage, the run-off at low water of the Summit water-shed would be insufficient. And the study was continued to determine the quantity flowing from the different sources with a view of storing the excess water of the feeders at times of high water to be utilized to supply the deficiency at low water.

The study of the run-off is rather involved, as the lumbermen have built storage dams at most of the lakes, the water of which they use in the spring and summer

to drive logs. These dams are opened and closed many times during the season, and require close watching to obtain correct results.

The two principle feeders are the Kai-bus-kong river, flowing from Lake Nasbonsing, and the North river; the latter having no large lakes.

Gauges were placed in Turtle lake, which is practically a continuation of Trout lake; Trout lake, Lake Talon and Nasbonsing lake (the principal feeder of Lake Talon, as already mentioned). As these gauges were directly affected by the condition of the dams, other gauges were placed, one in the Mattawa river below Trout lake, one on the Kai-bus-kong, below Nasbonsing lake, and one in the Mattawa river below Talon chute, where the gauge heights were proportional to the quantity of water flowing, and from which, with daily readings and measurements of flow, curves of the discharge and the quantity of water flowing from the water-shed were determined.

The measurements of flow commenced during February and March, 1905. Some difficulty was experienced in finding suitable sections for measurements. On the Kai-bus-kong, Menard's bridge formed a very convenient position for metering. About a mile below Turtle lake at the outlet to White Fish pond, a very good section for the work was found. At this section it was necessary for the observer to wade.

The river below Talon chute is a series of very deep ponds or small lakes, in which there is a very small current. These lakes are separated by rapids where the water is so agitated that proper metering could not be taken. Finally, after several of these places were tried, a section was found on Talon Lake Narrows, but it was necessary to relate the measurements to gauge heights taken at a gauge about a mile below Talon chute.

On Talon Chute Narrows, a cable-way was built, upon which a car was erected from which the measurements were taken.

The location of these sections is shown on plate 31.

In the study of the rainfall, Mr. Stupart, the director of the Meteorological Observatory in Toronto, has had rainfall observations taken at Lake Talon, North Bay, Mattawa and other places for a number of years, and very kindly loaned us a dozen rain-gauges to supplement these. A half dozen of these were placed in the water-shed of the Summit, viz.: one at Menard's bridge, one at Nasbonsing, one at Turtle lake, one at White Fish pond, one at Pimisi bay and one at Lake Talon, and arrangements were made with the water gauge readers to read the rain-gauge at the same time. These rain-gauges have been read from April 20, 1905.

As the water-shed will be somewhat altered when the canal is built, that is, the water surface, owing to the storage reservoirs, will be greater, and therefore the evaporation will be increased, two tanks were provided to measure the evaporation from the water surface. These were made of galvanized iron, four feet square and 18 inches deep, and were intended to be floated in the lake itself; one of the tanks was placed at Lake Talon, where one reservoir was to be and the other one at Lake Nasbonsing. Some difficulty was experienced in floating them owing to the waves breaking in at the corners. Finally they were buried in the sand at the side of the lake, and the sand around them kept moist.

Observations were made by the gauge readers twice daily as regards the temperature of the air, temperature of the water in the tank, temperature of the water in the lake, humidity of the atmosphere, pressure of the atmosphere and the general condition of weather, wind, &c.

From five to six months in the year some of the above observations were interrupted, that is, from December till the end of March or middle of April, when the moisture falls in the form of snow and does not melt until spring, except in exceptional seasons.

All the observations have been continued to date, the same sections being used in the summer time as are used in the winter.

PRECIPITATION.

The records of daily rain fall commenced on May 1, 1905, and have been carried on until the present.

The monthly results of the observations at the six stations are shown in tabulated statement No. 2. Together with these, are inserted results of Calvin, the station at which observations have been made since 1892 by the Meteorological Station in Toronto. Unfortunately, in some cases, the observations are not complete. 1899 lacks the months of December and April; 1895 has only two months, November and December; 1894 lacks the month of January and 1891 lacks the first three months of the year.

TABULATED STATEMENT No. 2.

RECORD of Precipitation at the Meteorological Stations adjacent to and in the territory of the water-sheds of the Ottawa and French rivers.

Year.	Stations.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total for Year.
1906	Nasbonsing Lake	2·35	1·70	2·08	1·01	2·79	3·41	1·93	2·40	2·46	3·47	3·53	......	....
1906	Menard's Bridge	2·34	1·74	2·16	1·01	3·13	4·13	4·17	2·70	2·66	3·39	3·58	......	....
1906	Whitefish Lake	2·10	1·88	2·25	1·16	3·44	4·06	2·97	2·58	2·65	3·30	3·99	......	....
1906	Turtle Dam	2·41	1·86	2·16	1·14	3·54	4·60	3·29	2·70	2·59	2·25	3·96	......	....
1906	Pimisi	2·88	1·16	2·91	1·09	3·59	3·32	1·93	2·51	4·10	2·18	1 11	......	....
1906	Lake Talon	2·88	1·16	2·91	1·04	3·58	3·63	2·05	2·50	4·03	2·16	1·31	......	....
1906	Calvin	2·97	1·68	1·52	0·70	......	2·58	......	......	......	......	......	......	....
1905	Nasbonsing Lake	......	......	......	......	3·48	4·16	2·24	1·28	3·47	3·65	2·00	1·39	....
1905	Menard's Bridge	......	......	......	......	3·46	4·58	2·80	1·46	4·10	3·99	2·09	1·32	....
1905	Whitefish Lake	......	......	......	......	3·48	4·44	4·00	1·80	4·22	4·46	2·43	1·49	....
1905	Turtle Dam	......	......	......	......	3·46	4·41	3·62	1·57	2·08	3·88	2·39	1·49	....
1905	Pimisi	......	......	......	......	3·24	3·32	2·34	0·91	3·09	2·90	1·78	1·87	....
1905	Lake Talon	......	......	......	......	3·62	3·46	2·24	1·12	3·37	2·79	1·49	1·92	....
1905	Calvin	2·67	2·75	0·70	0·99	4·05	5·01	3·12	1·38	3·15	3·56	1·63	1·86	30·87
1904	Calvin	1·41	1·32	2·19	3·04	3·08	2·49	1·45	3·80	7·17	2·57	2·12	2·43	33·07
1903	Calvin	2·08	3·31	2·67	0·71	2·65	3·56	5·70	3·45	4·97	1·95	1·56	3·78	36·39
1902	Calvin	2·12	1·71	2·76	1·37	2·78	4·44	4·67	2·18	4·92	3·95	2·92	2·23	36·05
1901	Calvin	2·27	0·45	2·90	1·22	2·76	2·21	2·81	3·99	1·70	3·40	2·55	2·78	29·04
1900	Calvin	1·15	3·05	2·30	0·77	2·34	3·49	3·73	3·03	5·20	1·76	2·04	2·29	31·15
1899	Calvin	2·29	0·63	6·56	......	2·59	2·37	8·50	0·43	3·85	2·31	1·57	......	....
1899	Mattawa	0·90	0·55	2·30		2·74	3·16	6·99	0·04	3·70	......	......	......	....
1898	Calvin	2·90	2·55	2·74	0·55	2·91	4·38	0·93	5·23	3·17	3·66	1·74	1·48	32·24
1898	Mattawa	2·98	3·65	0·98	0·60	......	2·61	6·86	0·75	2·95	2·13	0·93	1·06	....
1897	Calvin	2·71	1·84	2·39	2·96	3·13	3·56	3·10	3·91	0·89	4·05	2·22	3·91	34·67
1897	Mattawa	0·60	2·80	1·26	0·48	2·56	2·61	3·25	4·55	0·16	3·37	1·71	2·86	26·21
1896	Calvin	1·93	2·12	1·10	1·35	2·51	3·25	1·87	4·60	4·94	3·01	3·48	0·90	31·06
1896	Mattawa	2·35	1·10	1·55	1·00	0·63	2·94	3·99	4·05	4·56	2·80	4·22	0·30	29·49
1895	Calvin	......	......	......	......	......	......	......	......		......	3·47	3·09	....
1895	Mattawa	2·90	1·45	0·30	......	......	......	......	......	4·95	0·32	1·92	2·20	....
1894	Calvin	4·05	1·04	2·78	0·61	4·45	7·02	1·76	1·33	4·12	2·16	0·50	......	....
1893	Calvin	3·00	0·75	1·95	1·73	4·61	3·98	4·43	2·21	4·04	2·41	2·31	2·81	34·23
1892	Calvin	......	1·10	0·80	2·69	1·41	4·48	1·83	3·28	5·89	2·91	2·41	2·94	....
1891	Calvin	......	......	......	2·38	0·91	0·59	3·29	5·53	2·42	1·95	3·25	0·82	....

The complete rain-fall statistics, therefore, available for the summit are for the years 1891 to 1905, with certain months missing, as already mentioned. In comparing the results of our six stations with Calvin, we see that the yearly precipitation is about the same and from the similarity of rain-fall over the watershed, as shown from the daily records, it is thought that the results at Calvin for previous years can be assumed as applying to the entire watersheds with reasonable accuracy. The results, however, only covering fifteen years, require additional care in forecasting the years previous to 1891.

In addition to the daily and monthly records, the rain-fall has been divided into two periods, one extending from June 15 to December 1, and the other from December 1 until June 15.

From 1892 to 1904, the rain-fall was recorded monthly, therefore, for these years, the amount of precipitation from June 15 to July 1 was assumed as being one-half the rain-fall for the month of June.

			Inches.		Inches.
Dec. 1, 1905, to	June 15, 1906,		13·50	—June 15, to December 1,	15·69
" 1904	"	1905,	16·09	" "	15·32
" 1903	"	1904,	16·07	" "	18·35
" 1902	"	1903,	15·43	" "	19·50
" 1901	"	1902,	15·74	" "	20·86
" 1900	"	1901,	13·00	" "	15·56
" 1897	"	1898,	17·75	" "	16 92
" 1896	"	1897,	15·71		
" 1895	"	1896,	13·72	" "	19·53
" 1893	"	1894,	19·25		
" 1892	"	1893,			

It will be seen that from December 1 to June 15, the lowest winter precipitation was from December 1, 1900, to June 15, 1901, when it was thirteen inches. This was succeeded by a rain-fall of 15·56 inches from June 15 to December 1, 1901, and preceded by a rain-fall of 16·92 inches from June 15 to December 1, 1900.

The precipitation from December 1, 1905, to June 15, 1906, was the next smallest, being only one-half inch greater than from December 1 to June 15, 1900, but it was succeeded by a precipitation from June 15 to December 1, 1906, of 15·69 inches, and preceded by a rain-fall from June 15 to December 1, 1905, of 15·32 inches.

Although the precipitation from December, 1904, to June 15, 1905, was 16·09 inches, the run-off was considerably less than in the succeeding spring when the rain-fall was but 13·50. No thaws occurred in the winter time and the depletion of the ground storage from the very cold winter produced in the spring a very small run-off. Although in general, local information is not to be depended upon, still the method of regulating the water at the Summit gives the local information there some weight. One of the lumbermen's agents, Mr. O'Connor, who has charge of the lumber operations, stated that he had seen it once before in a period of twenty-three years as low as it was at that time. Others declared that it was the lowest in forty years. It can be safely assumed that the run-off was as low as what occurs in a cycle of ten years.

EVAPORATION.

Evaporation over the entire watershed, using evaporation in its broad sense, which includes the demands of plant life, is equal to the rain-fall minus the discharge. As previously stated, if our water-gauge records extended over a sufficient period of time, the question of evaporation and the climatic conditions on which it depends would not be so important as they are with only two year's water-gauge records.

The general character of the watershed will be very little different after the construction of the canal to what it is at the present time. If the character of the water-

shed were to be changed by clearing off the timber land, draining the swamps and cultivating with farm crops which would give an increased demand on the rain-fall, this subject would have to be considered in greater detail. Sufficient accurate data are not in existence from which to predict the effect of the change of the run-off when the character of the watershed changes. The watersheds which have been cleared and drained gave a much greater freshet flow in the spring, together with a corresponding low flow in times of drought and usually the total run-off for season of the same rainfall would be reduced in quantity. If the watershed is cultivated, then the demands of plant life are increased.

The entire subject is one of great complexity, and neither sufficient scientific data exist, nor could sufficient be collected during the course of the survey to safely predict what the run-off would be under changed conditions, and it is, therefore, stated as a broad principle at the beginning of this report that until such information is collected and the run-off safely forecasted, that no radical change of the watershed should be permitted unless arrangements were made to bring the water from an outside source, rendering the Summit independent of fluctuations. One particular change which will affect the water supply immediately is that, owing to the raising of Lake Talon about 40 feet, the water surface will be increased by 7·23 square miles. The evaporation from a water surface is greater than from the corresponding land surface. In the computation of the amount available for canal purposes, the method of computing eliminates the evaporation from the normal or unraised water surface of the principal lakes. The change of the water-shed is represented by the creation of 7.23 square miles of water surface where previously 7·23 of land area of a varying character existed. The result is that the water available for canal purposes is depleted to the extent of the increased evaporation over a water surface with that from a corresponding land surface. In our calculation, the run-off has been diminished by the evaporation from the water surface, not taking into consideration the land surface. This amount can be calculated from the formulæ deduced by various investigators from experimental data. But the quantity used in these calculations has been determined from the observations as taken in the field during the course of the survey. The monthly results of the daily observations are shown in tabulated statement No. 3 at the end of this report.

Plate No. 28 shows the principal observations of the Lake Talon water-shed, viz., the fluctuation of the lakes in which it is intended to store the surplus water, the daily rainfall and snowfall, the discharge in cubic feet per second, and the inflow curve or the amount of water available for navigation flowing into Lake Talon daily. The rainfall, snowfall and fluctuation of the lakes are obtained by daily observation.

From the current meter measuremnts the discharge curve was plotted, showing the discharge from the lake and the different heights of the gauge below Pimisi—Plate No. 29. Forty-eight measurements were taken of the discharge, which were used in constructing the curve. These measurements are shown in tabulated statement No. 4. The method of measurement is described in greater detail in part No. 2 of this report.

From this discharge curve, and the daily observed gauge heights, the discharge for the year as shown on Plate No. 28 was estimated. As previously mentioned, however, Lake Talon, Trout lake and Nasbonsing lake have been operated for years by the lumber interests as storage reservoirs in which to store sufficient water to drive the logs down the Mattawa and Kai-bus-kong rivers. The discharge curve below Lake Talon, therefore, represents the flow of the river as it is governed by the storage dams and their operation, therefore, on Plate No. 29, a curve has been plotted to show the daily run-off from Lake Talon available for navigation irrespective of the regulation by the lumber interests. From this daily inflow curve is calculated the size and effect of the reservoirs to be constructed and the amount of water available for canal purposes. As the proposed canal will affect Lake Talon, Trout lake (in which is included

Turtle lake) and Nasbonsing lake, and the rest of the water-shed will remain the same after construction as at the present time, we require only to determine the changed condition of the lakes affected for the present. If we denote the daily inflow of water from the water-shed into Lake Nasbonsing, Trout lake and Talon lake by D, and the daily discharge from Lake Talon as D_1, and the storage in Lake Talon, Trout and Nasbonsing as S, and the evaporation from their water surfaces as E, we find that D is equal to D_1, plus S plus E. Storage used with the plus sign as the lake rises, and the minus sign as it falls: the evaporation, of course, will always be plus, or, in other words, when the lakes are falling D is equal to D_1 minus S plus the evaporation in the three lakes.

The present area of the lakes is:—Talon, 5·69 square miles; Trout lake, 7·78 square miles; Turtle lake, 1·18 square miles and Nasbonsing, 6·54 square miles. After construction, the raised area of the lake will give additional water surface of 7·23 square miles. The amount of water available for canal purposes is equal to the daily inflow from the water-shed, minus the evaporation from the three lakes, minus the additional evaporation from 7·23 square miles, the additional evaporation meaning the increased evaporation from the water surface beyond that of the present ground surface which will be flooded.

As previously stated, for the purpose of our calculation, however, this has been estimated as additional water surface. The daily inflow from the water-shed at present equals the discharge from Lake Talon, plus the evaporation from the three lakes, plus storage in the three lakes, therefore, the amount available for canal purposes equals the discharge of Lake Talon, plus the storage in the three lakes, minus the evaporation from 7·23 square miles.

It is seen that $D = D_1 + S + E$

$$D - E = D_1 + S$$

$$D - E - E_1 = D_1 + S - E_1$$

where $D - E - E_1$ = water available for navigation, when these symbols are the same as above, and E^1 represents the evaporation from 7·23 square miles. The daily discharge, the storage evaporation, E_1 and available water are shown in tabulated statements 4 and 5, at the end of this report.

From the above hypotheses, the amount of water available for canal purposes was plotted as shown in Plate No. 28. For the purpose of comparison, the total amount of rain fall over the entire water-shed is plotted in cubic feet per second, but is shown as average rain fall of the month, instead of daily as the inflow curve is. The difference between these two is the entire evaporation of the water-shed, plus the additional evaporation of 7·23 square miles of water area.

The close of navigation is assumed to be November 30, therefore the water supply year will begin December 1 instead of January 1. It is assumed that on November 30 Lake Talon, as enlarged, is at elevation 671, and Lake Nasbonsing is also completely emptied. The problem is, how much water is available for canal purposes from May 1 to November 30 in the year of the least available flow. Until May 1, when navigation opens, all the water exclusive of the leakage can be accumulated in the storage reserves. After May 1, all excess water above the demands of navigation will accumulate until the flow is equal to the demands, or until the reservoirs are completely filled when wastage will occur. When the inflow available becomes less than the demands of navigation, then the additional water will have to be supplied from the storage. The two questions to decide are: Will the reservoirs always be full? and if they do fill from the date storage has to be called on, because the inflow is insufficient, will the storage added to the inflow in a minimum year of supply give sufficient water until November 30?

The amount of water available has been obtained by a series of approximations. The area of Lake Talon enlarged is 22⁴⁄₁₀ square miles. The amount of water which

this will take to fill six feet is 3,746,856,960 cubic feet. The area of Lake Nasbonsing is 6·54 square miles; to fill this six feet would require 1,093,948,416 cubic feet. It has been assumed that 50 cubic feet per second is sufficient allowance for leakage in the winter time. Therefore, the amount of water flowing from December 1 to May 1 in excess of this will go to fill the reservoirs.

In this connection, Lake Nasbonsing, whose area is 6·54 square miles, has a drainage area of 64·7 square miles.

The drainage area of Lake Talon being 342 square miles, therefore the amount tributary to Lake Talon independent of Lake Nasbonsing is 277·3 square miles. As the storage reservoirs in the proportion of 6.54 to 22·4 are practically equal to the proportion of the drainage area, and the rainfall is an average over the entire water-shed, it is safe to assume that the two storage reservoirs can be filled to the same height and may be treated collectively.

In the determination, it has been decided to calculate the amount of water available in a very low spring followed by a very low summer. These conditions, which are the worst possible that could exist, have not taken place in the Lake Talon water-shed, as evidenced in the rainfall statistics for the fifteen years for which we have the records. In the general discussion of the Ottawa river supply, rainfall statistics, more or less complete, are available for the last forty years.

It will be seen that the rainfall over the entire water-shed, of which Lake Talon water-shed forms a part, is subject to no very great fluctuation, and that the rainfall is fairly uniform over the entire basin. In the discharge curve of the Ottawa river, showing the amount of water flowing from the general water-shed for the last sixty years, never has a minimum winter and spring flow been followed by a minimum summer and fall flow. And although the principle of averaging a rainfall and a discharge from which to make deductions is to be deprecated, still, as it is seen in the larger water-sheds an abnormally low summer always succeeds an average or fairly high spring and winter flow, whereas a minimum winter and spring flow has always been followed by an average summer flow. It is, therefore, thought that in assuming the water supply available from a low winter and spring, followed by a very low summer and fall, this assumption which provides for the worst possible condition will more than compensate for the fact that our run-off statistics only extend over a limited period of time.

The continuous records of flow were commenced at the end of February, 1905. The measurement made at the end of February was 170 cubic feet per second. The inflow from March was 250 cubic feet per second. From December 1, 1904, until the end of February, 1905, no thaw occurred in January or February, but some slight thaws in December. The discharge, therefore, at the end of February would be less than at any other time during the winter, as the water is drawn from ground storage from the last thaw which occurred in December. The flow of January has been assumed at 200 cubic feet per second.

From the record of the Ottawa river and Calvin of 1904, it is seen that the month of December was initiated with a full ground storage.

In the spring of 1905, on this basis, allowing 600 cubic feet per second for the demands of navigation, the reservoirs will be full on May 10, and continue full until June 20, with the exception of a few days in May.

In the spring of 1906, the reservoirs are full on April 26, and continue full until June 15, 1906.

The total amount wasted in the spring of 1905, is 864,066,424 cubic feet, and the total amount wasted in the spring of 1906, is 1,096,719,424 cubic feet.

In both these cases the reservoirs are considered as completely empty on December 1. Our records show that there would be 8⅝ inches in the Talon reservoir on December 1, 1905.

The amount wasting in these two Springs, one of them the lowest in ten years, shows that the reservoirs will always fill and continue full until at least June 15. Flash boards could also be placed on the dams so as to carry the reservoir full until June 30, but, for the purpose of calculation, they are assumed as full until June 15, on which date the water stored will be drawn upon. At that time also ground storage is full. The conditions being the same for June 15 of each year, the minimum amount of water available for canal purposes will be obtained from the year in which the inflow from June 15 to December 1, is the minimum.

The period of 1906 has been noted, not only for the extreme drought, but for its long continuance: only three other years are comparable with it for the intensity of the drought.

The only complete records available for the Ottawa river water-shed are those in existence for the Rideau locks and the lower Ottawa.

A few scattered records have been obtained elsewhere. These records will be considered in detail in the general study of the water supply of the Ottawa river which forms part 2 of this report.

The years of extreme drought were 1846, 1881, 1887 and 1906. Each of these years had some particular feature, but the available water was about the same. This gives to the records of 1906, great value. To be certain, however, that sufficient allowance has been made for minimum conditions, a deduction of 10 per cent from the available water of 1906 in the months on which storage is called on, has been made. The reduction does not affect the other months, on account of the excess water wasting. With this allowance the available water for 1906 will be less than the records of sixty years show to have taken place, and denotes, therefore, a minimum supply which has been used as the basis of computation for the amount of traffic.

Immediately to the west of Lake Nasbonsing is situated the Wisawasa river and Wisawasa lake. The character of the water-shed is very similar to that of Lake Nasbonsing. Records were kept for the year 1905 of its outflow. The drainage area of the lake is 52·9 square miles, and the area of the lake proper is 2·8 square miles. A cut of 5,000 feet in length with a maximum depth of twenty feet would turn the water of the Wisawasa into Depot creek leading into Lake Nasbonsing. With a dam 10·7 feet high, this would give to the Summit an additional 750,324,833 cubic feet, allowing ten cubic feet per second for leakage of storage.

The total quantity of storage for the two water-sheds, therefore, in the year of minimum supply will be 5,591,130,309 cubic feet.

The results of these observations, which, for the purpose of calculation, are estimated in cubic feet per second per month are as follows:—

Month.	Discharge in c. ft. per second.	Evaporation in cu. ft. per second from 7.23 sq. miles.	Inflow available for navigation.	Wastage in c. ft. per second.	Condition of reservoir at end of month.
1904.					
December	....	....	230	50	0·60 ft. in R.
1905.					
January	....	....	200	50	1·09 "
February	....	....	150	50	1·39 "
March	....	....	250	50	1·87 "
April	619	....	1125	50	5·35 "
*May	743	17	939	129	Full.
†June	924	16	647	192	5·78 ft. in R.
July	429	19	155	85	4·18 "
August	409	17	125	85	3·03 "
September	152	11	148	85	2·00 "
October	209	10	244	85	1·24 "
November	424	....	324	85	0·72 "
Consider reservoir empty on Dec. 1, 1905.					
December	277	....	188	50	0.46 ft. in R. Empty.
1906.					
January	210	....	373	50	1·52 ft. in R.
February	127	....	168	50	1·87 "
March	187	....	213	50	2·41 "
Reservoir full on April 26, 1906.					
April	594	....	1332	143	Full.
May	730	17	690	134	"
†June	968	22	642	231	5·71 ft. in R.
July	317	35	47	85	4·31 "
August	440	27	160	85	3·20 "
September	99	24	29	85	1·80 "
October	155	11	184	85	0·80 "
November	215	....	255	85	Empty.

*Reservoir full on May 10th. †Reservoirs begin to drop on June 14. Allow 556 cubic feet per second.

It will be seen that the minimum conditions give 556 cubic feet per second. If we suppose this inflow is reduced by ten per cent, from June 15 to December 1, then the total available water is reduced by fourteen cubic feet per second, or a total of 542 cubic feet per second. The above reduction will only affect the months in which storage is called on, from June 15 to December 1, and will make ample allowance for minimum conditions.

It will be shown later that this minimum supply is sufficient for 10,000,000 tons of traffic, assuming present average size and capacity of lake carriers.

Supplementary sources have been investigated to provide for the demands of navigation if the traffic exceeds this amount.

An additional source of supply from which the water could be brought by gravity to the Lake Talon watershed is the Amable du Fond river. Its watershed is shown on Plate No. 31, and complete records for this river similar to those for the Lake Talon watershed were obtained.

Gauges were placed in the various large lakes at the head of the Amable du Fond river, and discharge curves similar to those for Lake Talon were made, extending from June 14, 1905, to the present time. Surveys were made of the large lakes for storage reservoirs. The results of these operations are shown on Plate No. 27. After the general survey was made which showed that the nature of the ground was such that the water of the Amable du Fond could be brought by either canal or tunnel and emptied into Sparks creek, which drains into Lake Talon, the detailed surveys were made by the parties in the field, and the cost are to be found in the general estimates.

The amount of water available from the Amable du Fond watershed is, in a minimum year, 700 cubic feet per second for seven months. This, added to the Lake Talon discharge, would give the total amount available 1,200 cubic feet per second, deducting feeder losses, etc., an ample and sufficient supply for 20,000,000 tons of traffic.

When vessels leave the Summit going westward, they enter Lake Nipissing immediately.

Going eastward, after leaving the Summit, the canal follows the Mattawa river to Mattawa. The two principal feeders of the Mattawa river are the watershed of Lake Talon and Amable du Fond river.

The character of the Mattawa river will be slightly changed, giving an additional water surface of 1.15 square miles.

The increased evaporations will amount to 3·3 cubic feet per second. The other feeders, exclusive of the Talon lake and the Amable du Fond river, will more than supply this, so that no additional draught on the Summit will be necessary.

Lake Nipissing, forming such a practically inexhaustible source of supply for canal purposes, its discharge being 3,600 cubic feet per second at low water, emphasizes the advantages which would be obtained if this supply could be made tributary to the summit. The cost of bringing 700 cubic feet per second from the Amable du Fond to Lake Talon by means of a gravity system will be comparatively heavy, and will be found in the estimate for the feeder.

For the purpose of comparison, an estimate of cost has been made for a pumping plant with which to supply the Summit from Lake Nipissing. It must be remembered that these supplementary sources of supply are only to be called on in case the amount of traffic exceeds 10,000,000 tons. A pumping plant has been designed which would take the water from about 1500 feet below the entrance of the locks to Lake Nipissing and discharge it the same distance above the upper entrance against a head of twenty-seven feet.

There are to be five (5) units each consisting of 1,000 H.P. motor, direct connected to a turbine pump of 200 cubic feet per second capacity. These pumps can keep the summit reservoir full and could be closed down for two months while the demands of navigation are supplied from the reservoirs. As they do not require to be run in the winter time, any repairs necessary can be easily made and the depreciation decreased.

The approximate cost of this installation, capitalizing the operating charges and depreciation, would be $40,000 a year on a capital outlay of $1,000,000.00. This is estimating on a separate power-plant at Deux Rivieres and a separate transmission line to the pumping-house, but as power will be required for lighting and operating gates on the Summit reach, this cost might be reduced by amalgamating the two systems into one and doing the pumping with the power when it was not required for other purposes.

As the supplementary systems are only to be called on in case the traffic exceeds 10,000,000 tons, the comparative advantages of the two systems, gravity and pumping, can be considered at greater length, before their installation is required.

It is understood that an objection exists against depending on pumps for the supply of the canal. Due consideration should be given to the fact that 95 per cent of the civilized world is depending upon pumps, both for the protection of their property and their lives, and these pumps are, practically operating without interruption. It seems that the prejudice against their use is unwarranted.

It is true that in no large canal has such a principle been resorted to for supplementing a deficiency in the water supply. Although such is the case with large canals, conditions at the Summit of the Georgian Bay canal are peculiar, in that, Lake Nipissing furnishes such an inexhaustible supply immediately to the west of the Summit that any engineer investigating would endeavour to find means to utilize it. In many of the smaller canals throughout Europe, pumps have been installed to feed different reaches of the same canal.

With the introduction of the electric motor, and direct driven turbine pumps, pumping particularly with low lifts, is cheap and free from chances of interruption.

In the Amsterdam Ship Canal (one of the largest ship canals of the world) the reverse process has been used. This canal serves as a large drainage canal for the marshes through which it runs, and up to a few years ago, this water was flushed out by flood-gates which created dangerous currents. A large pumping plant was installed to pump the excess water from the canal. This pumping-plant has been a success.

The sewage of many of the large cities of the world is pumped with lifts from three feet upwards. Such systems are installed in Chicago, Boston, New Orleans and several places in the Mississippi valley and elsewhere. Their use has been a success. Some individual pumps are pumping more per unit than those proposed at the Summit.

SECTION 2.—SUMMIT REQUIREMENTS.

The summit supply of a canal must usually furnish sufficient water for the following requirements:—

1st.—Power for electric lights.

2nd.—Power for operating gates.

3rd.—Leakage over spillways.

4th.—Leakage of the gates and sluices.

5th.—Evaporation and seepage.

6th.—Filling the locks.

Of these, the first, third, fourth and fifth are not affected by the amount of traffic. The second and sixth are directly proportional to the number of lockages.

After consideration it has been decided that the power for electric lighting and for operating gates, if electric power is adopted, should be brought from some outside source with a supplementary installation at each lock in case of interruption of the main source of power.

As the supplementary power is not likely to be required, and only in exceptional circumstances, and for a very short period, its installation cannot be considered as a draught upon the Summit supply.

Of the third item—leakage over the spillways and waste-ways. The main spillway is located at the foot of Talon chute, with a length of 220 feet at elevation 677.

The maximum summit level will be at this elevation and the water to be used for canal purposes will be stored in the Summit reach from elevation 671 to 677, and in other storage reservoirs.

Considering only the case of a minimum year, these reservoirs will be filled on April 30th. They will continue full and overflowing until June 15th. The entire leakage over spillways will be that caused by the wind dashing the water over in waves, but the loss will not effect the Summit supply as long as the reservoir is overflowing, but only from June 15th on, for, probably, a month.

The spillway with a length of 220 feet will have a leakage due to one inch of head of 11·7 cubic feet per second while, for two inches, it would be 33 cu. ft. and for three inches, 64·7 cu. ft. The west wind is the predominant wind at the Summit. From March 1 to Sept. 30, 1906, there were a total number of 95 days on which the wind blew from the west with more or less intensity. As the spillway can be arranged with splash-boards in case of excessive wind-storm, the losses from this cause could be but slight. An allowance of fifteen cubic feet per second, however, is made, which is ample.

The fourth: the leakage of the lock gates and sluices, is an uncertain quantity and, although the water supply for canals has been investigated and discussed many times, there seems to be no accurate determination of it. It varies with the character of the workmanship and the design, and there is no reason why any great amount should be allowed for it. Some experiments were made at the Soo to determine the leakage there.

From these and other data, the Deep Waterways Commission of the United States reported that the loss from this cause would be from 50 to 60 cubic feet per second for locks of 740 x 80 with a lift of 20 feet. The Inter-Oceanic Commission

made various assumptions, the final one being 225 cubic feet per second for double-locks, two with a lift of 28½ feet and two with a lift of 42½ feet. The locks are 900 feet long and have a width of 95 feet.

In consideration of these two reports, with the other data available, it would appear that 60 cubic feet a second would be ample to supply any possible loss due to the inefficient working or construction of the gates and sluices, and with careful construction, could be materially decreased.

The fifth consideration is evaporation and seepage. With ordinary construction, seepage through the dam should be prevented. Seepage through fissures in the rock is not expected to take place, but ten cubic feet has been allowed to provide for this. The evaporation from the lake surface has been deducted from the available water supply, as will be seen in its computation. It will, therefore, be reasonable to assume that the total losses or draught on the Summit supply from all other causes except lockages, amount to 85 cubic feet a second. The quantity of water remaining for lockages is 550 cubic feet a second. The number of lockages which a water supply will give has been studied many times.

It is reported on as follows by General Henry L. Abbott in Appendix E, of the Report of the Board of Consulting Engineers for the Panama Canal, 1906.

USE OF WATER FOR LOCKAGE OF VESSELS.

"Let

$Q =$ A lock full of water $=$ horizontal area of lock chamber times lift.
$D =$ Displacement of vessel.
$N =$ Number of locks in a flight.

The amount of water required to lock a vessel depends upon the condition—whether full or empty—that the vessel finds the lock, and also upon the direction—whether up or down—in which the vessel is passing.

There are four combinations of lockage. Following is a statement of each of the four combinations of condition, with a formula giving the amount of water which must be used for each condition. The formulaes are general and are for flights of locks. For a single lock, make $N = I$.

First: The ascent of a vessel next after one has descended, for which case the volume of water passing the upper gate is $V = NQ + D$.

Second: The descent of a vessel next after one has ascended for which case the volume of water passing the upper gate is $V = D$.

Third: The ascent of a vessel following one which has ascended, for which the volume of water passing the upper gate is $V = Q + D$.

Fourth: The descent of a vessel following one which has descended, for which case the volume of water passing the upper gate is $V = Q - D$.

All these formulaes contain the uncertain term 'D,' There are, however, two considerations, either one of which will cancel 'D.'

In both formulaes for descending vessels 'D' has the minus sign. The principal use of the formulaes is to obtain the amount of water drawn from the Summit level, and as all vessels which ascend to the Summit must again descend, it is evident that in getting the total amount of water used the displacement of the vessel will be cancelled.

The second consideration is that the first two conditions are equally likely to occur. Therefore, for vessels passing in alternate directions through a lock, the volume of water used per vessel is:—

$$V = \frac{NQ + D - D}{2} = \frac{NQ}{2}$$

The chances are also equal that the third and fourth conditions will occur. Therefore, for vessels passing locks in succession, the volume of water used per vessel is:

$$V = \frac{Q + D + Q - D}{2} = Q$$

It is not so clear that there will be equal chances that vessels will pass the locks alternately and in succession in a canal with a system of double-locks with quay or tie-up walls at the end arranged as they are in the designs for the Isthmian Canal locks.

The quay walls are arranged for the greatest convenience of vessels passing in succession, all up-bound vessels using one lock of a pair and all down-bound vessels using the other, and if the number of vessels should approach at all closely the capacity of the locks, no doubt the lockage would be arranged in that manner. Even if the number of vessels should be small it is probable that for the sake of convenience all vessels will be made to pass in succession. It is assumed, therefore, that such will be the case. The assumption is on the side of safety. However, let us assume for the moment that the chances that the vessels will pass the locks in succession and alternation are equal. In that case the volume of water used per vessel is:—

$$V = \tfrac{1}{2}\left(\frac{NQ}{2} + Q\right) = \frac{(N + 2)\ Q"}{4}$$

At the Nipissing end of the summit, the lock will have a maximum lift of thirty feet when the Summit level is full and a lift of twenty-four feet when the Summit is at its lowest level, or an average of twenty-seven feet. At the eastern end there will be two locks in flight with a thirty foot lift. These locks will be 650 feet long and 65 feet wide. Q, therefore, in the above formula, will be 650 x 65 x 27 = 1, 130,750 cubic feet for the western end and Q=650 x 65 x 30±1,267,500 cubic feet. At the Nipissing end when N = 1 V = $\frac{3}{4}$ Q, and at the eastern end when N = 2 V = Q. Each vessel passing through the Summit would use $\frac{3}{4}$ of 1,140,750 + 1,267,500 = 2,123,060 cubic feet. The total available water supply in a minimum year is 542 cubic feet per second. This leaves 457 cubic feet available for lockages, or 27,420 cubic feet per minute, which would allow a boat to pass every seventy-eight minutes, that is, there is sufficient water to furnish lockages at the rate of eighteen vessels per day. Although it is impossible to prophesy the style of traffic, for the sake of computation, it might be assumed as similar to that at the Soo. From these, an allowance of 2,500 tons per transit would seem to be correct. This would give 47,500 tons per day or approximately, 10,000,000 tons per year.

TABULATED STATEMENT No. 3.

MONTHLY rainfall, temperature, evaporation and weather at Bonfield, Ont., 1904, 1905, 1906.

	Temperatures.				Mean Relative Humidity.	Mean Barometric Pressure.	Precipitat'n.		Amount of Evaporation.	Evaporations per 24 Hours.	Direction of Wind.								Number of Quiet Observations.	Total Number of Observations.	Number of Clear Days.	Number of Cloudy Days.	Velocity of Wind Mean Miles per Hour.
	Water in Tank.	Water in Lake.	Mean Maximum.	Mean Minimum.			Amount.	Heaviest Fall in Month.			N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.					
1904.																							
December	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1905.																							
January	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
February	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
March	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
April	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
May	....	....	....	....	....	....	3·478	·901	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
June	61·90	64·04	79·4	50·3	70·0	....	4·162	·870	3·912	·130	....	....	....	....	....	....	....	....	....	....	....	....	....
July	70·50	72·70	84·1	57·3	72·9	29·40	2·820	1·020	4·383	·141	....	....	....	....	....	....	....	....	....	....	....	....	....
August	....	....	No re	cords.	....	....	1·280	·460	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
September	59·10	64·10	73·6	44·6	69·9	29·54	3·470	·900	1·700	·057	....	....	....	....	....	....	....	....	....	....	....	....	....
October	47·10	48·90	57·0	34·0	65·0	29·46	3·655	1·110	1·493	·048	....	....	....	....	....	....	....	....	....	....	....	....	....
November	31·99	32·09	39·0	23·0	....	29·33	2·005	·550	1·050	·035	....	....	....	....	....	....	....	....	....	....	....	....	....
December	....	....	32·3	11·3	....	29·48	1·390	·550	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1906.																							
January	....	....	34·3	8·4	....	29·32	2·350	·830	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
February	....	....	31·5	3·2	....	29·47	1·708	·653	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
March	....	....	36·0	·8	....	29·49	2·085	1·410	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
April	....	....	55·6	26·1	....	29·45	1·015	·415	·400	·080	....	....	....	....	....	....	....	....	....	....	....	....	....
May	54·3	52·9	63·1	36·9	....	29·36	2·795	·760	2·635	·085	....	....	....	....	....	....	....	....	....	....	....	....	....
June	69·1	70·7	78·2	53·5	....	29·44	3·413	1·050	3·303	·110	....	....	....	....	....	....	....	....	....	....	....	....	....
July	76·0	75·2	82·2	51·7	49·9	29·49	1·933	·750	4·543	·147	....	....	....	....	....	....	....	....	....	....	....	....	....
August	70·6	71·7	80·9	54·4	61·5	29·50	2·400	·850	3·212	·104	....	....	....	....	....	....	....	....	....	....	....	....	....
September	65·2	66·1	74·5	46·7	69 2	29·53	2·460	1·215	1·898	·063	....	....	....	....	....	....	....	....	....	....	....	....	....
October	46·2	50·1	58·2	36·4	64·1	29·49	3·470	1·190	1·342	·045	....	....	....	....	....	....	....	....	....	....	....	....	....
November	....	....	39·7	23·0	....	29·46	3·530	·930	·930	·030	....	....	....	....	....	....	....	....	....	....	....	....	....

TABULATED STATEMENT No. 3—*Continued.*

MONTHLY rainfall, temperature, evaporation and weather at Lake Talon, Ont., 1904, 1905, 1906.

	Temperatures.				Mean Relative Humidity.	Mean Barometric Pressure.	Precipitat'n		Amount of Evaporation.	Evaporations per 24 Hours.	Direction of Wind.								Number of Quiet Obervations.	Total Number of Observations.	Number of Clear Days.	Number of Cloudy Days.	Velocity of Wind Mean Miles per Hour.
	Water in Tank.	Water in Lake.	Mean Maximum.	Mean Minimum.			Amount.	Heaviest Fall in Month.			N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.					
1904.																							
December	......	......	14·8	6·1	......	......	2·430	0·710	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1905.																							
January	......	......	12·6	9·3	......	......	2.670	0.710	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
February	......	......	16·4	3·4	......	......	2·750	0·530	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
March	......	......	35·1	9·7	......	......	0·700	0·120	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
April	......	......	49·5	26·9	......	......	0·990	0·420	·360	·060	9	0	2	0	2	2	4	3	....	22	......	......	......
May	......	......	62·9	33·6	......	......	2·618	0·598	2·000	·064	2	2	3	1	4	0	13	1	....	26	......	......	......
June	64·7	66·1	75·4	48·5	86·5	......	4·171	0·791	2·563	·085	0	2	5	1	0	1	5	1	....	15	......	......	......
July	67·4	64·5	78·6	52·6	85·3	29·64	2·240	0·410	3·065	·099	1	1	7	2	4	2	11	0	....	28	18	13	......
August	62·9	68·4	77·0	45·1	89·0	29·68	1·126	0·420	2·776	·090	0	6	6	3	2	3	8	0	....	28	25	6	......
September	61·8	63·7	71·2	44·2	79·7	29·73	3·375	1·750	1·733	·058	3	2	12	0	1	0	11	0	....	29	19	11	......
October	50·7	53·9	54·2	30·0	71·0	29·69	2·795	·920	1·500	·048	0	3	6	0	0	1	15	0	....	25	12	19	......
November	......	......	33·6	21·3	......	29·48	1·476	·580	Frozen	......	3	0	10	0	4	0	7	6	....	30	3	27	......
December	......	......	32·3	11·3	......	29·63	1·923	·460	......	......	4	0	13	0	1	0	12	0	....	30	14	17	......
1906.																							
January	......	......	34·3	8·4	......	29·52	2·883	·500	......	......	3	0	11	0	2	0	10	1	....	27	....	......	......
February	......	33·5	31·5	3·2	......	29·76	1·168	·520	......	......	5	0	6	0	0	0	15	2	....	28	20	8	......
March	......	34·0	36·0	0·8	......	29·62	2·913	1·000	......	......	1	2	8	1	1	2	12	4	....	31	19	12	......
April	......	36·6	55·6	26·1	......	29·64	1·040	·440	·400	·080	4	1	8	0	1	0	13	3	....	30	16	14	......
May	......	51·9	64·0	36·9	67·6	29·62	3·580	1·045	2·608	·840	6	1	7	0	1	0	9	6	1	31	17	14	......
June	70·9	62·7	78·2	53·5	73·6	29·64	3·630	1·300	3·420	·114	1	0	17	0	0	0	11	1	0	30	14	16	......
July	74·1	77·0	82·2	51·7	74·4	......	1·595	1·050	5·233	·169	4	0	6	0	0	0	21	0	0	31	27	4	......
August	68·4	68·4	80·9	54·4	68·3	......	2·500	·730	4·091	·132	0	0	18	0	1	0	12	0	0	31	19	12	......
September	66·8	67·6	58·7	47·4	57·5	......	4·026	1·300	3·686	·123	2	0	9	0	0	0	19	0	0	30	19	11	......
October	48·5	53·4	57·7	39·9	67·4	......	3·422	1·400	1·912	·062	3	0	7	0	0	0	21	0	0	31	14	17	......
November	......	38·0	31·2	22·2	7·3	......	1·116	·575	·745	·026	1	0	14	0	4	0	11	0	0	30	11	19	......

TABULATED STATEMENT No. 3—*Continued.*

MONTHLY rainfall, temperature, evaporation and weather at Britannia Bay, Ont., 1904, 1905, 1906.

	Temperatures.						Precipitat'n				Direction of Wind.												
	Water in Tank.	Water in Lake.	Mean Maximum.	Mean Minimum.	Mean Relative Humidity.	Mean Barometric Pressure.	Amount.	Heaviest Fall in Month.	Amount of Evaporation.	Evaporations per 24 Hours.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Total Number of Observations.	Velocity of Wind Mean Miles per Hour.	Number of Clear Days.	Number of Cloudy Days.	Number of Quiet Observations.
1904.																							
December	......	......	16·1	1·8	......	30·03	1·890	0·500	......	......	3	14	7	1	1	7	13	16	62	......	24	7	0
1905.																							
January	......	......	15·7	0·9	......	30·11	3·290	1·920	......	......	5	12	2	2	0	6	21	12	62	......	23	8	2
February	......	......	18·3	0·9	......	30·11	1·480	0·450	......	......	2	7	8	0	3	11	17	7	56	......	21	7	1
March	......	......	33·0	14·9	......	30·12	1·200	0·520	......	......	4	13	6	3	3	4	12	5	62	......	28	3	2
April	......	......	51·6	31·9	......	29·79	0·950	0·350	1·100	·073	6	2	6	1	6	12	13	14	60	......	27	3	0
May	......	......	64·6	44·9	......	29·89	1·660	0·390	2·790	·090			No records.										
June	64·0	64·2	74·8	56·5	87·0	29·88	4·201	1·235	3·451	·115	2	8	9	1	0	4	25	2	60	7·5	25	5	9
July	70·3	70·9	80·2	61·6	79·3	29·71	5·208	1·210	4·908	·158	9	10	1	0	5	10	11	7	63	6·4	27	4	16
August	66·6	67·7	76·9	57·2	78·4	29·82	4·107	1·343	4·396	·142	9	6	0	6	3	8	12	5	60	5·3	25	6	12
September	58·2	58·8	69·5	51·1	83·9	29·89	1·988	0·916	2·640	·088	4	14	0	4	2	4	5	9	59	6·8	17	13	17
October	46·0	46·9	57·0	58·3	79·4	30·07	2·248	0·480	2·042	·066	2	5	3	2	0	5	10	15	60	6·1	23	8	18
November	......	......	37·9	25·3	80·0	29·94	1·600	0·640	1·342	·045						No records.							
December	......	......	29·1	14·2	......	30·04	2·330	0·640	......	......						No records.							
1906.																							
January	......	......	......	......	......	30·06	1·250	0·300	......	......	3	6	17	3	1	11	10	9	62	......	24	7	2
February	......	......	......	......	......	30·20	2·580	1·00	......	......	2	8	8	4	3	5	9	13	56	......	21	7	4
March	......	......	......	......	......	30·08	2·150	0·870	......	......	2	5	9	6	5	5	15	15	62	......	22	9	0
April	......	44·6	......	......	62·7	29·97	0·870	0·210	·960	·080	4	1	12	2	3	11	6	21	60	......	26	4	0
May	51·7	50·9	66·3	43·6	64·4	29·82	1·746	0·360	2·621	·085	10	3	12	1	10	5	9	11	62	......	24	7	1
June	62·9	63·0	78·3	56·4	66·0	29·80	5·023	0·990	3·447	·115	5	0	3	1	1	6	11	0	41	......	22	8	14
July	67·6	71·2	83·0	59·3	61·8	29·88	1·198	0·423	4·306	·139	3	5	2	2	0	4	6	6	59	18	24	7	31
August	67·1	72·5	82·5	60·7	66·7	29·87	2·705	1·330	5·487	·177	8	6	1	2	3	6	5	9	64	41	28	3	24
September	56·8	64·2	76·0	50·6	70·3	29·89	2·561	1·600	3·842	·128	5	6	3	0	4	9	8	10	60	41	23	7	15
October	44·5	50·9	57·3	40·2	75·8	29·83	3·859	1·050	1·825	·059	4	6	5	1	4	4	7	7	57	58	19	12	19
November	Frozen	36·9	40·7	25·1	78·5	29·92	2·176	·670	·990	·033	5	7	4	0	0	6	12	14	63	48	14	16	15

TABULATED STATEMENT No. 4.

LAKE TALON.

Current Meter Measurements.

Drainage of Lake Talon	334·0 square miles.
Area of Lake Talon	5.0 "
Elevation of zero of Lake Talon gauge above sea	631.82 feet.
Elevation zero of Lake Talon gauge, April 26, 1906, to June 16, 1906	637.69 "
Elevation zero of Pimisi gauge, July 17, 1906	582.21 "

Date.	Pimisi gauge.	Discharge.	Remarks.
Feb. 25, 1905	583·97	255	Section not suitable.
" 27, 1905	583·94	245	"
" 28, 1905	583·92	259	" "
Mar. 11, 1905	584·10	200	Talon Chute Narrows.
" 14, 1905	584·08	197	Below gauge below Pimisi.
" 14, 1905	584·08	200	" " "
" 27, 1905	584·46	337	Talon Chute Narrows
" 27, 1905	584·46	357	" "
" 28, 1905	584·49	304	" "
April 5, 1905	585·51	680	" "
" 5, 1905	585·51	658	" "
" 10, 1905	585·66	878	" "
" 10, 1905	585·66	721	" "
" 10, 1905	585·66	859	" "
" 11, 1905	585·69	875	" "
" 11, 1905	585·69	856	" "
" 17, 1905	585·76	918	" "
" 17, 1905	585·76	901	" "
" 25, 1905	584·20	253	" "
			(Talon dam closed 10 a.m., April 19.)
" 25, 1905	584·20	254	Talon Chute Narrows.
" 26, 1905	584·22	202	" "
" 26, 1905	584·22	220	" "
May 1, 1905	584·78	427	" "
" 1, 1905	584·78	468	" "
" 2, 1905	584·81	496	" "
" 4, 1905	585·17	601	" "
" 4, 1905	585·17	613	" "
" 6, 1905	585·23	626	" "
" 6, 1905	585·23	592	" "
" 9. 1905	585·52	736	" "
" 9, 1905	585·52	828	" "
" 13, 1905	585·41	751	" "
" 13, 1905	585·41	670	" "
" 16, 1905	585·43	704	" "
" 16, 1905	585·43	697	" "
" 22, 1905	585·81	849	" "
" 22, 1905	585·81	902	" "
June 6, 1905	586·11	918	Dammed by logs.
" 10, 1905	585·59	312	Taken through logs, unreliable.
" 12, 1905	585·68	220	Dammed by logs.
" 16, 1905	586·23	1,150	Talon Chute Narrows.
" 16, 1905	586·23	1,099	*See* letter of June 29.
" 23. 1905	586·21	1,186	Talon Chute Narrows.
" 23, 1905	586·21	1,098	" "
July 13, 1905	583·41	65	150′ below gauge below Pimisi.
Aug. 25, 1905	584·29	135	Pimisi dam opened, Talon dam closed.
" 26, 1905	584·11	173	Pimisi dam opened 1 gate, Talon dam closed.
July 17, 1906	584·19	222	

TABULATED STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

March, 1905.				April, 1905.				
Day.	Discharge.	Storage.	Discharge from Talon. Chute.	Storage.				Total.
		Talon Lake		Talon.	Trout.	Turtle.	Nasbonsing.	
1.........	140	− 37	610	520	251	68	200	1,659
2.........	135	− 37	630	520	251	68	200	1,669
3.........	143	− 37	660	520	251	68	200	1,699
4.........	150	− 37	690	520	521	68	200	1,729
5.........	160	− 37	720	520	251	68	200	1,759
6.........	170	− 37	680	520	251	0	200	1,831
7.........	180	− 37	885	520	251	100	50	1,606
8.........	190	− 37	870	130	125	30	0	1,155
9.........	200	0	850	130	125	30	0	1,135
10.........	210	0	840	135	125	30	0	1,130
11.........	208	0	850	130	125	30	90	1,235
12.........	206	− 80	870	130	125	100	90	1,215
13.........	204	− 85	880	130	95	25	90	1,220
14.........	200	− 80	910	130	95	25	90	1,250
15.........	198	− 80	950	0	95	25	90	1,160
16.........	196	0	910	− 120	95	25	90	1,000
17.........	195	20	890	− 120	95	25	90	980
18.........	193	37	870	− 120	95	25	− 100	770
19.........	190	37	850	0	95	25	− 150	820
20.........	195	37	260	400	95	25	50	830
21.........	220	− 182	230	400	100	− 50	− 100	580
22.........	230	− 30	230	400	100	+ 20	− 50	700
23.........	230	− 100	240	400	100	+ 20	0	760
24.........	225	− 40	240	400	100	20	0	760
25.........	230	0	240	400	100	20	50	710
26.........	235	200	250	400	100	20	− 50	720
27.........	237	206	250	400	100	0	− 50	700
28.........	243	300	300	400	100	60	50	910
29.........	260	800	360	400	100	60	100	1,020
30.........	300	825	390	400	100	60	100	1,050
31.........	410	825	....	....	....	....	....	....
Total......	....	....	18,595	....	....	....	....	33,752
Average...	....	....	619	....	....	....	....	1,125

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

MAY, 1905.

Day.	Discharge.	Storage.				Total.
		Talon.	Trout.	Turtle.	Nasbonsing.	
1	420	500	125	50	0	1,095
2	470	367	125	50	− 25	987
3	500	367	125	20	75	1,087
4	600	367	125	20	100	1,212
5	610	300	125	60	20	1,115
6	640	250	125	50	20	1,085
7	670	200	125	60	20	1,075
8	700	200	125	60	20	1,105
9	770	200	150	60	50	1,230
10	780	50	150	40	50	1,070
11	740	− 122	150	25	− 50	743
12	710	− 122	150	60	− 50	748
13	700	− 122	150	60	25	813
14	680	0	150	60	25	915
15	670	0	150	60	25	905
16	720	200	150	− 60	0	1,010
17	970	366	0	− 10	0	1,326
18	1,000	300	− 80	0	0	1,220
19	1,010	29	− 80	25	− 25	959
20	1,010	29	− 80	− 30	− 50	879
21	980	− 153	− 80	0	− 50	697
22	930	− 153	− 80	0	0	700
23	890	− 153	− 80	0	0	657
24	840	− 150	− 80	0	0	610
25	760	− 150	− 80	0	0	530
26	740	− 150	− 80	− 25	0	485
27	720	− 200	− 80	− 25	0	515
28	700	− 217	− 80	− 10	− 200	193
29	680	− 217	− 80	− 20	− 200	163
30	705	0	− 80	− 10	− 200	415
31	700	0	− 80	− 30	100	690
Total	32,025	....	....	....	....	25,034
Average	743	....	....	....	....	839

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

JUNE, 1905.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	90	10	50	10	0	....	760
2	720	− 20	50	10	− 200	18	542
3	700	15	50	10	− 200	14	561
4	590	117	50	10	100	14	853
5	490	110	50	10	50	14	696
6	940	− 50	50	10	50	14	986
7	700	− 200	50	10	0	25	535
8	500	− 200	50	10	50	0	410
9	1,150	− 300	50	10	0	13	897
10	810	− 200	50	10	50	38	682
11	840	− 200	145	30	0	26	789
12	860	− 200	145	30	0	20	815
13	1,180	− 360	145	30	200	0	1,195
14	1,190	− 390	145	50	200	0	1,195
15	1,180	− 350	145	50	0	31	994
16	1,150	− 325	145	50	0	13	1,007
17	1,150	− 350	145	− 60	25	13	897
18	1,150	273	− 250	− 60	25	74	1,164
18	1,150	50	− 250	− 60	25	25	890
20	1,305	− 380	− 250	− 75	25	0	625
21	1,160	− 300	− 250	− 300	25	13	320
22	1,120	− 300	− 250	− 25	− 100	16	429
23	1,080	− 330	− 250	− 40	50	0	510
24	1,020	− 380	− 250	60	− 100	25	325
25	1,000	− 480	− 125	50	− 100	25	320
26	940	− 540	− 125	− 25	75	18	307
27	910	− 620	− 125	− 25	75	25	190
28	− 840	− 655	− 125	− 25	50	25	60
29	700	− 550	− 125	− 25	− 75	25	− 100
30	500	0	− 125	− 25	− 75	0	275
Total	27,715	....	....	....	....	504	19,427
Average	924	....	....	....	....	16	647

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

JULY, 1905.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	250	0	− 66	0	0	20	164
2	210	− 150	− 66	− 60	0	30	− 96
3	180	180	− 66	− 60	0	25	209
4	180	− 20	− 66	30	− 30	14	80
5	190	272	− 66	− 30	− 400	7	41
6	150	272	− 66	0	− 190	0	164
7	130	272	− 66	0	− 190	38	108
8	95	272	− 66	30	− 190	13	118
9	160	272	− 66	− 40	− 190	25	111
10	220	272	− 66	− 40	− 190	25	171
11	200	272	− 66	− 30	− 200	25	151
12	140	272	− 66	− 30	− 200	5	111
13	90	272	− 66	− 40	− 200	0	56
14	70	272	− 66	0	− 200	30	46
15	70	272	− 66	0	− 200	25	51
16	70	272	− 185	− 75	− 50	0	32
17	80	272	− 185	− 75	− 50	18	24
18	930	272	− 185	− 70	300	12	1,035
19	1,050	272	− 185	− 66	− 100	30	947
20	1,030	− 424	− 185	− 60	0	7	354
21	300	− 424	− 185	− 30	0	25	− 364
22	150	− 424	− 185	− 30	− 100	0	− 579
23	600	120	− 185	− 75	50	38	472
24	1,040	− 433	− 185	− 75	50	52	345
25	1,080	− 433	− 185	0	50	20	492
26	960	− 433	− 185	− 50	50	10	332
27	900	− 433	− 185	− 10	− 75	18	179
28	780	− 433	− 185	− 10	50	0	202
29	730	− 433	− 185	− 10	− 70	30	102
30	650	− 433	− 185	− 10	0	31	11
31	620	− 433	− 185	0	0	33	40
Total	11,305	....	....	....	....	606	4,768
Average	429	....	....	....	....	19	155

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

AUGUST, 1905.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	610	—350	—125	0	0	5	130
2	600	—340	—125	0	0	13	122
3	590	—333	—125	—75	—50	38	—31
4	580	—333	—125	—75	50	14	83
5	570	—333	—125	—75	0	14	27
6	550	—290	—125	0	0	27	108
7	540	—260	—125	0	0	27	130
8	510	—197	—125	0	—100	13	75
9	350	—197	—125	0	— 50	13	— 35
10	340	—197	— 50	—50	0	2	41
11	330	—197	— 50	—50	0	25	18
12	300	— 50	— 50	—25	— 75	13	87
13	400	0	— 50	—25	— 75	30	220
14	670	—310	— 50	—25	— 75	13	197
15	500	—200	— 50	—25	— 75	13	147
16	440	0	— 50	0	0	25	365
17	400	— 20	— 50	—30	0	25	275
18	400	— 68	— 50	0	0	13	269
19	400	— 60	— 50	0	0	25	265
20	400	45	— 50	—40	0	20	335
21	400	20	— 60	0	0	23	337
22	400	0	— 60	—15	0	13	312
23	400	0	— 60	—15	0	30	295
24	400	0	— 60	—15	0	13	312
25	300	— 75	— 60	—15	—200	25	— 75
26	200	—127	— 60	—30	—200	13	—230
27	70	50	— 60	—30	—100	13	— 83
28	380	—220	— 60	—30	—100	13	— 43
29	350	—157	— 60	—30	—100	10	— 7
30	160	90	— 60	0	—300	10	—120
31	150	182	— 60	0	100	25	347
Total	12,690					546	3,876
Average	409					17	125

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

SEPTEMBER, 1905.

Day.	Discharge.	Stoarge.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	150	— 91	15	15	75	0	164
2	150	0	15	20	— 75	25	85
3	150	40	15	20	40	4	261
4	160	95	15	0	40	4	306
5	160	95	15	0	40	4	306
6	160	0	15	0	40	8	207
7	165	0	15	0	40	12	208
8	165	0	15	0	—100	6	74
9	180	0	15	0	100	10	285
10	250	— 50	—100	—30	0	12	58
11	350	—100	—100	—30	0	6	114
12	355	—109	—100	—10	0	18	118
13	360	— 75	—100	—10	— 50	14	111
14	110	— 75	—100	—30	100	10	— 5
15	110	91	165	60	0	2	424
16	110	0	165	30	0	5	300
17	95	200	165	0	140	7	593
18	80	167	165	0	140	7	545
19	78	167	165	60	140	4	606
20	140	167	165	60	0	25	507
21	170	167	— 50	—25	0	25	237
22	130	50	— 50	—25	0	18	87
23	180	—100	— 50	—25	0	18	— 13
24	140	40	— 50	—12	—150	16	— 50
25	90	0	— 50	—12	—150	16	—138
26	100	—100	— 50	— 0	—150	21	—221
27	110	—100	— 50	—10	—150	16	—216
28	50	—100	— 50	—12	—150	12	—274
29	60	100	— 50	—15	—150	14	— 74
30	50	0	— 50	—15	—150	12	—177
Total	4,558	....	....	....	....	351	4,428
Average	152	....	....	....	....	11	148

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

OCTOBER, 1905.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	60	110	— 50	0	—200	0	— 80
2	70	130	— 50	0	—100	40	10
3	75	130	— 50	0	—100	13	37
4	100	145	— 50	0	—100	25	70
5	150	140	— 50	—10	—100	13	117
6	160	110	— 50	—15	— 50	25	130
7	160	50	— 50	—15	0	36	99
8	160	— 35	— 50	—15	0	13	47
9	160	— 20	— 50	—15	50	13	112
10	150	30	65	—15	150	5	375
11	150	70	65	40	0	7	318
12	165	85	65	45	50	0	402
13	180	40	65	50	0	8	327
14	200	— 50	65	0	0	6	209
15	240	—160	65	0	0	4	140
16	260	—220	65	0	0	4	100
17	240	—230	65	0	100	2	173
18	230	—130	100	68	100	8	316
19	210	— 10	100	60	100	9	451
20	210	80	100	70	100	8	552
21	240	100	100	60	0	6	504
22	250	60	100	0	0	6	404
23	250	0	100	0	0	4	346
24	260	— 40	100	30	40	2	388
25	300	—100	100	0	40	2	338
26	280	— 90	100	45	40	4	350
27	285	—110	100	0	40	4	311
28	285	—100	0	50	40	3	272
29	340	—150	0	—30	40	3	197
30	270	—165	0	0	40	4	240
31	380	—155	0	0	40	4	260
Total	6,570					300	7,562
Average	209					10	244

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

NOVEMBER, 1905.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	390	— 90	50	20	0	No evaporation.	270
2	350	— 90	0	0	—211		49
3	335	— 90	— 75	—30	—211		— 70
4	338	— 90	— 75	—30	—211		— 68
5	350	180	— 75	10	—211		254
6	370	185	— 75	—10	—211		259
7	380	180	— 75	—10	—211		274
8	400	180	— 75	—10	—211		294
9	420	180	— 75	—10	—221		304
10	430	180	— 75	—10	—211		314
11	435	205	— 75	—10	—211		344
12	440	180	— 75	10	—211		324
13	470	180	0	10	—211		449
14	470	180	0	10	—211		449
15	470	185	—125	10	—211		325
16	470	180	—125	10	—211		324
17	470	— 90	—125	—60	—211		— 16
18	470	— 90	—125	—60	—211		— 16
19	470	0	125	50	—211		434
20	470	0	125	50	0		645
21	470	— 30	125	50	0		615
22	450	— 30	— 40	—20	150		510
23	430	— 30	— 40	—20	0		340
24	430	—150	— 40	—20	50		270
25	410	—140	— 40	—20	50		260
26	430	—140	— 40	—20	50		280
27	440	—140	— 40	—20	50		290
28	430	140	170	50	50		840
29	410	—310	170	50	50		990
30	435	— 80	170	50	50		625
Total	12,720	....	....	....	....	....	10,162
Average	424	....	....	....	....	....	324

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

DECEMBER, 1905.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	420	—120	0	0	50	No evaporation.	350
2	400	— 30	0	10	50		430
3	390	0	0	0	0		390
4	390	0	0	0	0		390
5	370	— 82	0	10	0		300
6	350	— 82	0	—25	0		243
7	335	— 82	0	0	0		253
8	320	— 82	0	0	0		238
9	310	— 82	0	0	0		228
10	310	— 82	0	0	50		278
11	310	— 82	0	0	50		268
12	300	— 82	0	0	0		208
13	290	— 82	0	0	0		198
14	280	— 82	0	0	50		238
15	270	— 82	0	0	0		178
16	260	— 82	—200	—68	25		— 75
17	250	— 82	—200	—68	0		— 90
18	250	— 82	—200	—68	0		—100
19	250	— 82	0	—10	0		143
20	235	— 82	0	—10	0		128
21	220	— 82	0	5	20		153
22	210	— 82	0	5	20		138
23	195	— 82	0	5	20		133
24	190	— 82	0	5	20		133
25	190	— 82	0	5	20		133
26	190	— 82	0	5	20		148
27	215	— 82	0	0	20		178
28	240	— 82	0	0	20		188
29	250	— 82	0	0	20		178
30	240	— 82	0	0	20		168
31	230	— 82	0	8	20		176
Total	18,575						5,827
Average	277						188

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

JANUARY, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	240	— 50	0	0	0	No evaporation.	190
2	240	— 60	0	0	0		180
3	240	— 65	0	0	0		175
4	240	— 60	0	0	44		224
5	250	— 50	0	0	44		234
6	230	— 40	0	0	44		234
7	230	— 40	0	0	44		234
8	230	— 45	0	0	44		229
9	220	— 45	0	0	44		229
10	220	— 30	0	0	44		234
11	215	— 30	0	0	44		234
12	210	— 20	0	0	44		239
13	210	— 5	0	0	44		249
14	210	— 5	0	34	44		283
15	210	— 5	35	34	44		318
16	210	— 5	35	0	44		284
17	210	— 5	35	0	44		284
18	210	— 50	35	0	44		239
19	200	— 25	35	0	44		254
20	200	— 8	35	0	44		271
21	200	55	35	0	44		334
22	210	310	35	0	168		723
23	220	815	125	37	168		1,365
24	240	460	125	37	168		1,030
25	230	0	125	37	168		560
26	200	300	125	37	168		830
27	180	620	125	37	168		1,130
28	190	—158	125	37	0		194
29	160	—158	125	37	0		164
30	140	—158	125	37	0		144
31	130	—158	125	37	75		209
Total	6,530	....	....	....	....	....	11,501
Average	210	....	....	....	....	....	373

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

FEBRUARY, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	125	0	125	34	23	No evaporation.	307
2	120	0	125	68	23		306
3	120	0	125	34	23		302
4	130	0	125	10	23		288
5	130	168	0	10	23		331
6	130	5	0	10	23		168
7	130	5	0	10	23		168
8	130	5	0	10	23		168
9	130	5	0	10	23		168
10	130	5	0	10	23		168
11	125	5	0	10	23		163
12	125	5	0	—15	23		138
13	125	5	—65	—15	23		73
14	125	5	—65	—15	23		73
15	125	5	—65	—15	23		73
16	125	5	—65	—15	23		73
17	125	5	—65	—15	23		73
18	125	5	—65	—15	23		73
19	125	5	—65	—15	23		73
20	125	5	—65	—15	23		73
21	130	10	25	5	23		193
22	130	20	25	5	23		203
23	130	—90	25	5	23		97
24	130	— 5	25	5	23		118
25	130	0	25	5	23		183
26	130	0	25	5	23		183
27	130	5	25	5	23		188
28	130	10	25	5	23		193
Total	3,565						4,707
Average	127						168

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

MARCH, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	130	10	0	0	20	No evaporation.	160
2	130	10	50	15	20		225
3	130	10	50	17	20		227
4	130	10	50	17	20		227
5	130	10	50	17	20		227
6	130	10	50	0	0		190
7	130	10	0	0	20		160
8	130	15	0	0	20		165
9	140	10	0	0	20		170
10	150	10	0	0	20		180
11	160	10	0	0	20		190
12	165	5	0	0	20		190
13	165	5	—40	—10	0		120
14	165	5	—40	—10	50		170
15	165	5	—40	—34	0		96
16	165	5	—40	—34	0		96
17	175	15	—40	—20	0		130
18	190	18	—40	—10	0		158
19	200	30	—40	—10	0		180
20	240	—10	—40	—10	0		180
21	238	— 8	—40	—10	0		180
22	238	— 8	—40	—10	0		180
23	238	0	—40	—20	0		178
24	238	0	—40	—20	0		178
25	238	0	35	—20	0		253
26	238	122	35	—20	200		575
27	290	275	35	10	0		610
28	240	160	35	10	0		445
29	240	—90	35	10	0		195
30	240	—90	35	10	0		195
31	240	—90	35	10	0		195
Total	5,790						6,625
Average	187						213

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

APRIL, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	250	60	50	20	0	No evaporation.	380
2	260	60	50	0	0		370
3	280	60	50	0	0		410
4	310	—180	50	0	86		266
5	258	0	50	0	100		408
6	258	— 88	260	146	75		653
7	240	— 88	260	146	100		738
8	240	— 88	260	45	75		532
9	240	— 88	260	45	86		543
10	240	— 88	260	45	86		543
11	238	— 15	260	45	86		614
12	238	— 15	260	45	86		614
13	238	— 15	260	45	86		614
14	238	— 15	260	45	86		614
15	280	— 15	260	71	86		682
16	330	— 15	260	71	86		732
17	540	3,130	260	71	0		4,001
18	700	3,130	260	71	200		4,361
19	840	3,130	260	71	86		4,387
20	860	3,130	260	71	86		4,407
21	900	3,130	125	71	0		4,226
22	940	—245	125	71	0		891
23	980	—245	125	71	0		931
24	1,100	—245	125	10	70		1,060
25	1,240	—245	125	10	70		1,200
26	1,138	—245	125	10	70		1,098
27	1,138	—245	125	10	70		1,098
28	1,100	—245	125	10	70		1,060
29	1,100	—245	125	10	70		1,060
30	1,100	—245	125	10	70		1,060
Total	17,822						39,973
Average	594						1,332

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

MAY, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	1,020	80	50	11	77	22	1,216
2	980	—180	50	11	77	14	924
3	900	180	50	11	77	22	1,196
4	880	— 77	50	11	77	20	921
5	830	— 77	50	11	77	22	869
6	820	— 77	50	11	77	14	867
7	800	— 77	50	11	77	14	847
8	750	— 77	50	11	77	14	797
9	730	— 77	50	11	77	14	777
10	695	— 77	50	11	77	15	741
11	695	— 77	100	11	77	17	789
12	720	77	100	68	77	24	958
13	780	454	100	68	77	20	1,059
14	820	454	100	0	77	24	1,427
15	860	0	100	0	—100	25	835
16	860	0	0	0	—100	25	735
17	860	90	0	0	50	14	966
18	860	90	—100	—26	50	17	869
19	880	—100	—100	—26	—150	14	490
20	910	—728	—100	—26	0	17	39
21	770	—728	—100	—26	0	17	—100
22	730	—242	—100	—26	25	15	372
23	700	—242	—100	—53	—25	21	259
24	240	—242	—100	—53	—25	10	—187
25	390	—242	—100	—53	—25	10	444
26	310	260	—100	—53	70	6	481
27	350	260	—100	—53	70	10	517
28	380	260	—100	—53	70	17	540
29	540	260	—100	—53	—210	20	417
30	730	260	—100	—53	—210	19	608
31	840	260	—100	—53	—210	14	723
Total	22,650					527	21,396
Average	730					17	690

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

JUNE, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	970	90	— 85	— 50	—200	20	705
2	950	180	— 85	— 50	0	16	979
3	1,000	—350	— 85	0	400	16	949
4	1,020	50	— 85	0	0	25	960
5	1,430	—730	— 85	— 10	—400	12	193
6	800	—100	— 85	— 10	100	14	700
7	630	—100	100	0	100	14	716
8	960	280	100	40	0	20	1,300
9	1,240	—270	100	40	0	20	1,090
10	1,280	—200	100	40	0	25	1,199
11	1,330	—150	100	0	0	20	1,260
12	1,400	—200	— 75	— 15	0	22	1,088
13	1,490	260	— 75	0	0	20	1,135
14	1,360	—260	— 75	0	100	17	1,108
15	1,190	—610	— 75	— 30	0	25	450
16	1,140	—515	— 75	— 30	0	20	500
17	1,100	—440	— 75	0	0	20	565
18	1,050	—420	— 75	0	0	16	439
19	970	—380	— 75	0	0	16	500
20	900	—344	— 75	— 50	0	30	400
21	890	—376	— 75	— 15	0	30	403
22	760	—270	— 75	— 15	0	20	380
23	730	—270	— 75	— 15	0	51	319
24	710	—260	— 75	— 15	0	10	350
25	690	—245	— 75	— 30	— 50	18	272
26	650	—213	— 75	0	— 50	13	299
27	630	—230	— 75	0	— 50	65	210
28	610	—250	— 75	— 50	— 50	64	120
29	600	—273	— 75	— 40	— 50	20	143
30	580	—155	— 75	— 40	— 50	5	155
Total	9,000					684	19,285
Average	968					22	642

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

JULY, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	560	10	—125	—50	0	0	395
2	540	50	—125	—50	0	38	377
3	520	50	—125	—50	0	38	362
4	500	50	—125	—50	0	25	350
5	490	50	—125	—50	0	25	342
6	430	50	—125	—50	— 75	25	205
7	400	48	—125	—50	—200	65	8
8	380	50	—125	—50	—200	30	22
9	360	50	—125	—50	— 50	34	151
10	330	50	—125	—50	—100	25	80
11	300	360	—125	—50	—100	13	372
12	280	110	—125	—50	—100	38	77
13	230	116	—125	—50	—150	51	—30
14	190	118	—125	—50	—150	25	—85
15	200	114	—125	—50	—150	50	—61
16	230	112	—125	—50	—150	50	—33
17	230	112	—125	—50	—150	50	—33
18	230	112	—125	—50	—150	49	—32
19	230	112	—125	—50	—150	61	—44
20	230	110	—125	—50	—150	14	0
21	230	—110	—125	—50	—200	25	—60
22	250	110	—125	—50	—100	25	60
23	280	115	—125	—50	—100	38	82
24	290	112	—125	—50	—100	38	89
25	260	—234	—125	—50	0	25	—175
26	240	—232	—125	—50	0	14	—181
27	240	—230	—125	—50	0	14	—179
28	250	—215	—125	—50	0	51	—190
29	280	—230	—125	—50	0	51	—170
30	310	—230	—125	—50	0	79	—175
31	350	—230	—125	—50	0	....	—55
Total	9,830	....	....	....	....	1,046	1,469
Average	317	....	....	....	....	35	47

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

AUGUST, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	400	—420	— 35	— 20	0	25	-100
2	460	—420	— 35	— 20	0	25	- 40
3	520	—420	— 35	— 20	0	25	20
4	550	—420	— 35	— 20	- 50	25	0
5	580	—420	— 35	— 20	10	30	85
6	610	—420	— 35	— 20	10	30	115
7	690	—420	— 35	— 20	10	14	211
8	750	—420	— 35	0	10	14	190
9	810	—420	— 35	0	10	38	327
10	830	—420	— 35	0	0	8	367
11	840	—420	— 35	0	0	14	370
12	800	—420	— 35	0	0	25	320
13	770	—420	— 35	0	— 40	25	250
14	740	360	— 35	— 20	— 40	25	260
15	670	90	— 35	— 20	— 40	25	460
16	600	180	— 35	— 20	— 40	25	660
17	530	180	— 35	— 20	— 40	25	590
18	430	182	— 35	— 20	— 40	25	592
19	390	—270	— 35	— 20	— 40	12	15
20	350	—270	— 35	— 20	0	14	11
21	370	—130	0	0	0	14	126
22	190	—130	0	0	0	25	35
23	140	—130	0	0	0	12	0
24	130	—130	0	0	0	13	—13
25	110	—130	125	0	0	25	80
26	100	60	125	+ 50	—200	75	60
27	90	60	125	+ 50	—200	75	50
28	80	60	125	50	—200	38	77
29	70	60	—125	— 20	—200	38	—253
30	70	60	—125	— 20	—200	40	—255
31	60	60	—125	— 20	—200	25	—250
Total.	13,630	.....	.....	.....	.....	839	4,960
Average.	440	.....	.....	.....	.....	27	160

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

SEPTEMBER, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1..	60	100	— 25	— 50	0	25	60
2..	60	100	— 25	0	0	64	75
3..	65	100	— 25	0	0	64	75
4..	65	100	— 25	0	0	25	115
5	65	0	— 25	0	0	25	15
6	65	0	— 25	0	0	25	15
7	65	0	— 25	0	0	38	2
8..	65	0	— 25	0	0	12	32
9..	80	52	— 25	0	0	12	— 9
10..	100	52	— 25	0	0	12	11
11..	160	52	— 25	— 15	0	12	56
12..	460	52	— 25	— 15	0	4	374
13..	200	52	— 25	— 15	0	20	78
14..	110	52	— 25	— 15	— 25	55	— 62
15..	80	52	— 25	— 15	— 25	25	— 62
16..	70	52	— 25	— 15	— 25	30	— 67
17	70	52	— 25	— 15	— 25	32	— 81
18	60	52	— 25	— 15	— 25	13	— 70
19..	50	52	— 25	— 15	— 25	13	— 80
20	58	52	— 25	— 15	— 25	13	— 72
21	50	52	— 25	0	— 25	13	— 65
22..	58	— 50	— 25	0	10	33	30
23..	50	— 50	— 25	0	10	16	— 30
24..	50	— 50	— 25	0	10	17	— 30
25	50	— 50	— 25	0	10	13	— 2
26	70	— 50	25	0	10	22	— 16
27..	140	— 50	— 25	0	10	64	211
28..	170	— 50	— 25	0	10	25	80
29..	180	0	— 25	0	10	13	152
30..	170	0	— 25	0	10	7	137
Total..	2,966	....	....	....	....	742	871
Average...	99	....	....	....	....	24	29

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

OCTOBER, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1..	170	— 10	0	0	0	17	143
2..	150	— 10	0	0	0	15	125
3..	130	— 10	0	0	0	25	95
4..	110	— 10	0	0	0	25	75
5..	110	— 10	0	0	0	10	90
6..	100	66	0	0	0	6	160
7..	105	66	0	0	—211	10	— 50
8..	110	66	0	0	—211	15	— 50
9..	120	66	0	0	—211	10	— 30
10..	130	66	0	0	—211	12	— 27
11..	140	66	0	0	—100	12	94
12..	140	66	0	0	0	12	194
13..	145	66	0	0	100	12	299
14..	150	66	0	0	— 25	12	129
15..	150	66	0	0	— 25	16	125
16..	150	66	0	0	— 25	18	123
17..	160	66	0	0	— 25	17	134
18..	170	66	0	0	100	19	117
19..	170	66	0	0	100	4	332
20..	175	66	0	0	0	8	233
21..	175	66	0	5	0	8	238
22..	175	66	20	5	55	8	313
23..	175	66	20	5	55	7	314
24..	170	66	20	5	55	10	306
25..	170	66	20	5	55	6	310
26..	185	66	20	5	55	8	324
27..	200	66	20	5	55	6	340
28..	210	66	20	5	55	8	348
29..	210	0	20	5	0	10	225
30..	210	0	20	5	0	10	225
31..	200	0	20	5	0	6	219
Total..	4,865	....	....	....	....	362	5,677
Average..	155	....	....	....	....	11	184

STATEMENT No. 4—*Continued.*

SUMMIT WATER SUPPLY.

NOVEMBER, 1906.

Day.	Discharge.	Storage.				Evaporation.	Total.
		Talon.	Trout.	Turtle.	Nasbonsing.		
1	190	— 60	0	0	20	No evaporation.	150
2	180	— 60	0	0	20		140
3	177	— 60	0	0	20		137
4	178	60	0	0	20		250
5	179	60	0	0	20		259
6	180	60	0	0	20		260
7	180	45	0	0	20		155
8	176	45	0	0	20		151
9	178	10	0	0	20		208
10	180	10	0	0	20		210
11	180	10	0	0	20		210
12	180	10	0	0	20		210
13	182	10	0	0	20		212
14	195	10	0	0	20		225
15	200	10	0	0	20		230
16	205	10	0	0	20		235
17	206	10	0	0	20		236
18	210	10	0	0	20		240
19	215	10	0	0	20		245
20	220	10	0	0	20		250
21	228	10	0	0	20		258
22	238	60	0	0	20		318
23	240	60	0	0	20		320
24	252	60	0	0	20		332
25	260	60	0	0	20		340
26	273	60	0	0	20		353
27	275	60	0	0	20		355
28	290	60	0	0	20		370
29	312	60	0	0	20		392
30	335	60	0	0	20		405
Total	6,478						7,656
Average	215						255

TABULATED STATEMENT No. 5.

PROBABLE AMOUNT OF EVAPORATION AS REPRESENTED BY INCREASE IN WATER SURFACE AREAS AT SUMMIT.

Evaporation over 7·55 square miles water surface in cubic feet per second
7·55 square miles is 210,481,920 square feet.
One-tenth of one inch over this area gives 20·3 cubic feet per second.

Day.	1905.					1906.					
	June.	July.	Aug.	Sept.	Oct.	May.	June.	July.	Aug.	Sept.	Oct.
1	......	..20.3	5·0	0	......	22·6	20·3	......	25·4	25·4	17·0
2	18·5	30·0	13·0	25·4	40·0	13·6	16·2	38·0	25·4	64·3	15·0
3	13·6	25·4	38·0	3·5	13·4	22·0	16·2	38·0	25·4	64·3	25·4
4	13·6	13·6	13·6	4·1	25·4	20·3	25·4	25·4	25·4	25·4	25·4
5	13·6	7·0	13·6	4·1	13·4	22·0	12·2	25·4	30·0	25·4	10·5
6	13·6	·0	26·9	8·2	25·0	13·6	13·5	25·4	30·4	25·3	6·1
7	25·4	38·0	27·3	12·3	36·0	13·6	13·5	64·9	13·5	38·0	10·5
8	·0	13·0	13·0	6·1	13·0	13·6	20·3	30·4	13·5	22·0	15·2
9	13·0	25·4	13·0	10·1	13·0	14·2	20·3	33·9	38·0	12·0	10·5
10	38·0	25·4	2·0	12·1	5·3	15·0	25·4	25·4	7·5	12·0	12·5
11	25·4	25·4	25·4	6·0	7·1	16·8	20·3	14·0	13·5	12·0	12·5
12	20·3	5·0	13·0	18·3	8·1	24·4	22·2	38·0	25·4	4·0	12·5
13	·0	·0	30·1	14·2	8·1	20·3	20·3	50·8	25·4	20·3	12·5
14	......	30·0	13·0	10·0	6·0	24·3	17·0	25·4	25·4	55·1	12·5
15	31·0	25·0	13·0	2·2	4·0	25·4	25·0	50·0	25·4	25·4	16·4
16	13·0	·0	25·4	5·4	4·0	25·4	20·3	50·0	25·4	30·2	18·2
17	13·0	18·3	25·4	6·5	2·1	13·8	20·3	50·0	25·4	32·0	17·0
18	73·6	12·2	13·0	6·5	8·0	16·8	16·2	49·0	25·4	13·0	19·5
19	25·4	30·0	25·4	4·0	9·1	13·8	16·2	60·6	12·2	13·0	4·5
20	·0	7·0	20·3	25·4	8·0	16·8	30·4	13·6	13·5	13·0	8·1
21	13·0	25·4	22·5	25·4	6·0	16·8	30·4	25·4	13·5	13·0	8·1
22	16·2	.0	13·0	17·5	6·0	15·0	20·3	25·4	25·4	33·0	8·1
23	·0	38·0	30·0	18·3	4·0	20·5	50·7	38·0	12·1	16·0	7·5
24	25·4	52·2	13·0	16·2	2·0	10·1	10·2	38·0	13·0	7·0	10·1
25	25·4	20·3	25·4	16·2	2·0	10·1	18·3	25·4	25·4	13·0	6·0
26	18·2	10·1	13·0	21·0	4·0	6·0	12·8	13·6	75·0	22·3	8·1
27	25·4	18·0	13·0	16·2	4·0	10·1	64·6	13·6	75·0	64·0	6·0
28	25·4	·0	13·0	12·1	3·0	16·8	63·9	50·8	38·0	25·4	8·1
29	25·4	30·0	10·0	14·2	3·0	20·3	20·0	50·8	38·0	15·6	8·1
30	·0	30·5	10·0	12·2	4·0	19·0	5·0	79·0	40·1	7·0	10·2
31	......	32·9	25·4	......	4·0	13·8	......	......	25·4	......	......
Total	507·3	608·8	548·	353·	290·	526·	697·	1067·	813·	746·	362·
Average	17·	19·	18·	12·	9·	17·	23·	35·	27·	24·	11·

NOTE.—The area 7.23 square miles should have been used for this computation but owing to the very slight difference no change was made.

ALEXANDER McDOUGALL.

STORAGE AND REGULATION OF FLOW.

The question of controlling, partially at least, the flow on all the rivers utilized for the waterway, and thus create practically a slack water navigation system with least possible fluctuations, it is of vital importance, and is one of the necessary elements of the project.

This control is not only necessary for safe navigation at flood time, but is also desirable for all the commercial and industrial interests on these rivers.

Safe navigation in restricted natural streams subjected to great variations of flow, demands that all excessive currents be suppressed, that cross currents be avoided and that excessive fluctuations of levels be decreased.

Objectionable currents are very much intensified during flood time, and the reduction of the flood flow combined with such enlargement of the restricted sections of the river as may be commercially possible is the only effective remedy.

On the three main natural streams utilized for the waterway this question presents different aspects.

The regulation of flow for the French river does not present any peculiarity requiring special study. The source of the river is Lake Nipissing, of relatively large area, which has very little fluctuation, and on which the periodical high and low water are yearly and always at about the same time. The river oscillates with the lake, and the relation of its low flow to extreme flow is as one to four. Its extreme oscillation is from 8 to 10 feet in some of the restricted parts. The French river as it leaves Lake Nipissing is very favourable to the construction of controlling dams which will govern the lake level at any desired elevation, and thus prevent low water. Ordinary care will have only to be exercised to manipulate the regulating dams in proper time to prevent the water on the lake from rising higher than the proposed working level. At all times the supply of water is more than ample and waste will be of no consequence.

On the Mattawa river section of the canal which includes the Summit reach, the problem is more complex. Though the spring flow is abundant, there is a serious deficiency in the summer and autumn. The problem is to conserve the water which now goes to waste and reserve it for the period of deficiency. Moreover, the question of a supplementary source of supply with feeder canal is involved, and the whole has required the most careful investigation. The data collected, with analysis of conditions and deductions made are given in the part of the report relating to Summit water supply.

The problem on the Ottawa river which is intimately connected with its canalization, is the control of its flood waters, especially during extreme years.

The flood discharge is sometimes as much as 15 times and over that of the low discharge, and it is of the greatest importance to reduce the ratio of extreme and low flow.

A fortunate characteristic of the river is that it is not subjected to sudden rises. This is a very favourable feature for the successful control by means of large natural storage reservoirs such as may probably be created at the head-waters of the Ottawa and its main tributaries.

Before giving the result of the studies made in this connection, a few general considerations in regard to this question of storage may be of general interest.

The method of storage reservoirs for river improvement has been extensively tried in France, Russia and America. In the United States it has been particularly applied on the Upper Mississippi river with marked success. Reservoirs filled in the spring

during freshet season serve to increase the flow later in the year when the streams run low. Floods may thus be prevented or greatly reduced if only adequate storage capacity is available, and with a judicious selection of reservoir sites. But the question of artificial reservoirs for the storage of waters is intimately connected with the preservation of forest areas at the sources of supply. All investigations made by careful observers in the leading countries of the world have led to the conclusion that forests are great regulators of streams, in fact that they are nature's most perfect reservoirs, and that artifical basins are only an attempt to improve and supplement what forests can accomplish. No artificial remedy can be either adequate or permanent, if forests are not preserved on the higher slopes of the streams. Their function in reducing the difference between high and low water, and in decreasing the periods of drought is now recognized. In many countries of Europe, where forest clearing had at first been carried out indiscriminately, the increase in the recurrence of great floods on some of the streams, as well as their sudden rises, attracted the attention of the different governments to the necessity of reforestration of water sheds as a means of regulating stream flow, and large sums of money have been expended thereon.

In the United States, the timber famine which began to be felt a few years ago was the primary cause of the inauguration of a national forest policy, and in many cases, it is stated, this policy has been the means of securing benefits by restraining the run-off at flood times, and checking the erosion of the higher slopes.

In the annals of the American Academy of Political and Social Science, Hon. Gifford Pinchot, United States Forester, gives the results of some observations made in relation to these questions, which are of great interest. He states as follows:—

'A careful study of the behaviour of the stream flow in several small timbered and non-timbered catchment areas in the San Bernardino mountains of southern California, made by Professor Tourney for the Forest Service in 1902, brought out in a most convincing manner the effect of the forest in increasing surface run-off and sustaining the flow of mountain streams.

Three timbered areas were studied. These gave during December—a month of unusually heavy precipitation—a run-off of but five per cent of the heavy rainfall for that month; during the following months of January, February and March they gave a run-off of approximately 37 per cent of the total precipitation, and three months after the close of the rainy season, still supported a well sustained stream flow.

At the same time, the neighbouring non-timbered catchment area under observation gave during December a run-off of 40 per cent of the rainfall and during the three following months a run-off of 95 per cent. In April the run-off was less than one-third of that from each of the forested catchment areas and in June the stream from the non-forested areas was dry.'

It is evident that the exploitation of the forests of this country must be regulated rigidly not only because the timber supply is already visibly diminishing, but because also the forests gradually distribute the moisture they receive, which slowly finds its way to the rivers, instead of rushing in torrential streams as is the case in denuded land, causing floods and carrying soil matter which fill the natural regulating basins. The importance therefore of combining forest preservation with storage reservoirs for the proper regulation of streams is too apparent to be elaborated at any length here.

The style of river navigation proposed for the Ottawa, and the only one admissible, is the 'dam and lock' system, with practically slack water reaches. From Mattawa, where the ship canal joins the Ottawa river, down to Montreal, fifteen ponds or reaches of various lengths are formed, which it is necessary to maintain at certain fixed elevations.

Fluctuations in these ponds must not be permitted to take place below the regulated water surface, fixing the depth of 22 feet above grade, nor must it fluctuate much above that surface for safe navigation, in order to reduce currents and maintain a navigable

channel without unnecessary excavation in shallow parts, or excessive height in lock walls and lock gates. The head pond at Mattawa receives the waters of the whole Upper Ottawa, and the other basins below, in addition to the head-waters, have to receive and pass supplementary contributions from tributaries, some of which are important streams with large flood discharge. Therefore the scheme of storage had to be judicially considered as a whole and the reservoirs distributed over the catchment area in such a way that they will give the required control over the flood waters of the main stream as well as individual control of some of the main tributaries flowing into intermediate basins.

In the studies made, the extreme flood flow of 1876, the highest on record, was taken as a basis for calculations. For low water the record year of 1846 was taken.

The crest of the flood of 1876 was not only the highest, but the run-off for the whole year was also the largest with the exception of that of 1890. As no similar high water has been observed since, none having been close to it, the computations made as based on this extreme record are amply safe.

During the period of the survey, it was earnestly hoped that extreme high water should occur in order to verify by direct measurements the computations and estimates made as to volumes and duration of extreme flood flow.

The maximum volume of flow has been estimated and based upon the known maximum heights obtained at a few points in 1876, and upon the study of smaller floods measured subsequently. It would have been of the greatest interest to check the hydraulic problem of regulation as solved, from an assumed standard flood, but unfortunately nature did not favour the survey in that respect. On the other hand conviction exists that the deductions made are on the safe side, and in the spring of 1906, we were fortunate enough to have the water in the Ottawa-Hawkesbury reach, which receives the largest tributary of the Ottawa,—the Gatineau—at about the level selected for regulation, and opportunity was offered to check the calculated hydraulic grade, flow, &c., at that elevation with very satisfactory results.

Observations then taken, confirmed the decision already reached that such high water as that of 1906 would not be too excessive for the proposed waterway, and it was decided to determine if sufficient storage existed to control the river in a year of maximum flood so that the extreme flow would not exceed that of 1906.

The study of the storage problem, therefore, was commenced first by collecting and tabulating the fluctuations of the river and its discharge at certain points along the route, paying particular attention to the flood of 1876 and the exceedingly low waters of 1846, 1881 and 1887.

The hydraulic history of the river below Ottawa, practically since 1844, was graphically reconstituted, and is given on plate No. 30, showing daily discharge, monthly precipitation and mean monthly temperature.

From the discharge curves obtained, a determination was made of the excess flow above the stage at which it was desired to control the river, and preliminary surveys made to ascertain if 25 per cent more storage than was required from these figures, was available, the 25 per cent surplus being to allow for the inaccuracy of existing maps and data available.

In initiating the preliminary surveys for the storage, it was not expected that a complete solution could be found in a short time, but that sufficient preliminary data could be collected to show that partial control at least was possible at reasonable cost. Its complete determination would take several seasons, and extensive surveys would be required to select suitable sites for all dams and determine accurately the capacity of all reservoirs. This I am not ready to recommend unless the construction of the canal is decided. In that event, a hydraulic bureau should at once be formed to carry on systematic surveys and establish gradually the storage system during the construction of the canal.

But even should construction be delayed, I would strongly recommend that preliminary studies, and the collecting of hydraulic data be continued, and it is my intention to keep a few men at that work unless otherwise instructed.

The subject is of such great importance that the report of Mr. Alexander McDougall, hydraulic engineer, who was directed to conduct some investigations on this question, will be given in extenso, in order that all the information available so far, may be recorded here. A brief reference, however, may be made to a few of the points mentioned therein.

The Ottawa river has a total drainage area of 56,048 square miles, which is very large as compared with its total length of 720 miles, traversing a territory of about 550 miles.

In a spring of low flood at the head of Montreal island, the Ottawa flows about 150,000 cubic feet per second; in an ordinary spring, it flows nearly 200,000 cubic feet, and in the flood of 1876, it is stated that it discharged the very large amount of 350,000 cubic feet per second, which is record high water. This figure, however, of 350,000 cubic feet is uncertain, and it may have been over-estimated.

The corresponding low water flows at the mouth are from 20,000 to 30,000 cubic feet per second.

The fluctuations in water level between extreme low and high water at Ste. Anne (head of Montreal island) are 11½ feet; at Grenville, 19 feet; at the foot of Rideau Locks, Ottawa, 25 feet; and at Lake Deschenes 9½ feet.

At other points in the river, it fluctuates according to the situation.

The greatest flow of the Ottawa is about 12 to 17 times the lowest, whilst that of the Niagara river, which is regulated by the large natural storage reserves of the Great Lakes above, is but 1.7 times the lowest, and the fluctuations in the St. Mary's, St. Clair and Detroit rivers are very slight, which is highly favourable to navigation, and renders possible the enormous traffic passing through them. It is hoped and confidently expected that artifical storage will do for the Ottawa what the natural storage of the Great Lakes does for the rivers above mentioned and for the St. Lawrence.

The reduction of flood level and the increase of low water flow which a well regulated storage and release of waters will give, will not only benefit navigation, but will also benefit lumber interests and all industries depending on water powers.

It is known that large lake pondage exists in the Upper Ottawa basin, which can be artificially increased by dams constructed at reasonable cost. The existence of such large lake storage, and of large and dense forests is the fortunate condition of the Ottawa river watershed. In a rocky country, where the surface run-off is naturally extreme in relation to the rainfall, if such pondage did not exist, very disastrous floods would take place which could not well be suppressed.

On the Mississippi river, many years ago, a project was elaborated for the construction of 65 reservoirs at the head-waters of the river. Five of these reservoirs have been built, and already it has been possible to maintain a higher stage of navigation in the upper river above St. Paul by releasing during the low season the reserve water collected.

It is stated that all the different interests on that river, navigation, logging, mills, riparian owners, etc., are all unquestionably better off with the reservoirs than without them. The storage capacity of these reservoirs is 96 billion cubic feet of water. Some statisticians have estimated that each billion cubic feet is at present worth to the milling industry of Minnesota $13,000 a year or a total of $1,218,000.

The effect of storage was considered more minutely for the Besserer's Grove section below Ottawa by reason of our more complete records. It is estimated that the entire reservoir capacity required above low water is nearly 20,000 square miles by one foot, with a factor of safety of at least 25 per cent as mentioned previously.

The investigations made so far indicate that at least this storage exists above the section at Besserer's Grove.

Assuming a possible average height of storage of ten feet, which is a low average, as the North country is entirely uninhabited, and no great damage can be done by the raised water surfaces in the reserve lakes, this represents a combined lake area of 2,000 square miles.

A list of lakes visited, with their approximate area and possible storage capacity is given in the report of the hydraulic engineer, as well as a list of other lakes which it has not been possible to investigate.

Tables of the hydraulic data of the river will also be found in that report.

The following tables show the permissible flow in the Ottawa river when canalized, also the minimum flow resulting from storage, as compared with the present minimum discharge at three principal points, Mattawa, Ottawa and head of Montreal island.

MATTAWA.

DRAINAGE AREA—19,663 SQUARE MILES.

Years.	Yearly mean run-off in cubic feet per second, Jan'y 1 to Dec'r 31.	Maximum flow in cubic feet per second	Minimum flow, cubic feet per second	Permissible maximum flow 22 foot navigation project, cubic feet per second.	Storage available above Mattawa, square miles by 1 foot.	Minimum flow resulting under proposed storage, cubic feet per second.	Estimated rise of low water level in feet at Klock's.
1876.		May.	October.				
Year of maximum discharge.......	30,000	113,000	8,000	45,000	12,500	22,000	4.25
1860.		May.	Septemb'r.				
Year of average discharge.......	26,000	58,000	12,000	45,000	12,500	23,000	5.75
1877.		May.	March.				
Year of minimum discharge.......	14,000	35,000	7,500	45,000	12,500	16,000	2.75

CHAUDIERE FALLS, OTTAWA.

DRAINAGE AREA—34,623 SQUARE MILES.

Years.	Yearly mean run-off in cubic feet per second, Jan'y 1 to Dec'r 31.	Maximum flow in cubic feet per second	Minimum flow, cubic feet per second	Permissible maximum flow 22 foot navigation project, cubic feet per second.	Storage available above Ottawa, square miles by 1 foot.	Minimum flow resulting under proposed storage, cubic feet per second.	Estimated rise of low water level in feet at Deschênes Lake.
1876.		May.	October.				
Year of maximum discharge.......	52,000	123,000	10,500	90,000	14,500	36,000	2.5
1860.		May.	Septemb'r.				
Year of average discharge.......	46,000	103,000	21,000	90,000	14,500	49,000	3.5
1877.		May.	March.				
Year of minimum discharge.......	28,000	62,000	10,000	90,000	14,500	29,000	2.0

HEAD OF MONTREAL ISLAND.

DRAINAGE AREA—55,700 SQUARE MILES.

Years.	Yearly mean run-off in cubic feet per second, Jan'y 1st to Dec'r 31st.	Maximum flow in cubic feet per second	Minimum flow, cubic feet per second	Permissible maximum flow 22 foot navigation project, cubic feet per second.	Storage available above Montreal, square miles by 1 foot.	Minimum flow resulting under proposed storage, cubic feet per second.	Estimated rise of low water level in feet at Lower Carillon.
1876.		May.	October.				
Year of maximum discharge.......	83,000	310,000	22,000	155,000	20,000	58,000	3.0
1860.		May.	Septemb'r.				
Year of average discharge.......	75,000	166,000	34,000	155,000	20,000	79,000	4.0
1877.		May.	March.				
Year of minimum discharge.......	44,000	100,000	20,000	155,000	20,000	45,000	2.0

NOTE.—The flow resulting from storage is calculated from the spring of one year to the spring of the following year.

DETAILED REPORT BY MR. ALEXANDER McDOUGALL ON REGULATION AND STORAGE POSSIBILITIES.

OTTAWA RIVER AND TRIBUTARIES.

STORAGE.

The route of the proposed Georgian Bay canal is from Georgian Bay up the French river to Lake Nipissing into Trout lake at the head of the Mattawa river, and then following the Mattawa and the Ottawa rivers to Montreal.

The French and Ottawa rivers are generally a series of deep lake-like expansions separated by rapids or falls. The general system of improvement proposed has been the construction of dams at the heads of these rapids to retain the waters at certain prescribed levels in the different reaches.

In the Upper river reaches, this level is much above the ordinary high water level, but in general, the permanent improved level will be about that of the present high water. In conjunction with these governing dams and the necessary locks to overcome the difference in the level of the various reaches, a general system of storage is necessarily required to control the flow of the main river. These are subject to no sharp fluctuations, but their seasonable variations are extreme and the proper navigation of the rivers cannot be assured if the flow is left in its present uncontrolled state.

The ideal waterway for safe and economical navigation has unrestricted channels of slack water.No inland waterway can be made absolutely ideal according to the above standard, but it is essential that it should be so constructed that the traffic for which it is designed can be accommodated with safety when vessels are in charge of competent navigators.

In an extreme year, the Ottawa river continues in a state of flood for a period of from five to six weeks. If this flow were left uncontrolled, navigation would be interrupted during this period. The enlargement of the section necessary to carry away this flood flow without the creation of dangerous currents would be an almost impossible commercial undetaking.

A study of the control of the river was, therefore, commenced shortly after the beginning of the main surveys in order to determine the degree of control possible and the amount advisable. This study included the surveys of storage reservoirs at the head-waters of the main rivers and their principal tributaries together with all available records concerning the flow of the river and its general hydraulic conditions. This study embraced the entire water-shed of the Ottawa and French rivers, a total area of some 63,000 square miles. With the time available and the lack of information prior to this survey, it was not possible to determine absolutely the most minute details, but it has been sufficient to show that the water-shed tributary to the ship canal furnishes ideal opportunities for effectual control for all portions of the river.

Sufficient storage reservoirs were located and visited which would control the flow of the river at a stage at which it will create no dangerous currents to navigation.

Other reservoirs of large size are known to exist in the unsurveyed and unexplored territory, and it is proposed that these should be surveyed in the near future. The determination whether these additional reservoirs are to be built or otherwise is one entirely of cost, each new reservoir reducing the cost of the locks and dams, but increasing the storage cost.

In many countries, elaborate systems of control have been constructed, particularly in Northern Russia and in the United States. None of these, however, are quite so extensive as that proposed for the Georgian Bay canal. The Russian system was designed to assist navigation; that of the northwestern states at the head-waters of the Mississippi was designed to assist navigation at Minneapolis and also the water-power, and furnish other incidental advantages.

The advantages, aside from navigation, which will be gained by the present proposed system of control of the Georgian Bay canal route, would of themselves pay for the construction of a large portion of it. This is particularly true with respect to the Chaudière industries at Ottawa and milling interests at other localities.

The system of control in existence in the northwestern states has been described as follows in the Report of the Chief of Engineers, United States Army:—

Reservoirs at Head Waters of Mississippi River and Minnesota River between Brainard and Grand Rapids, Mich.

> The project adopted January, 1880 called for the construction of forty-one reservoirs in Minnesota and Wisconsin.
>
> The object of these reservoirs is to collect surplus water, principally from precipitation of winter, spring and early summer, to be systematically released during the low water season so as to benefit navigation on the Mississippi river below.
>
> The reservoir system was built by the Government primarily for the benefit of navigation in the Mississippi river, and incidentally to mitigate its floods. The system is operated by impounding the waters in excess of the natural low water flow at times when this excess is not needed by navigation, and releasing during the low water season of navigation such a volume of water as will maintain the gauge at St. Paul at a constant height as much above low water as the available water in storage will permit. Without the addition of stored waters from the reservoir system, the river at St. Paul is liable to fall to a state of 0·2 feet, as happened in July and August, 1894, or to zero, as happened in April, 1896, whereas, with judicious and economical use of the reservoir waters it is quite practicable to keep the gauge at St. Paul from ever falling below three feet. This is a very substantial benefit to navigation. On the 424 miles of river above St. Paul, where the stream is smaller, a still greater effect can be obtained.
>
> The effect of the reservoirs in mitigating the floods of the upper Mississipi is equally pronounced. A flood stage existed this season from Sandy river to Aitkin, Minn., and below, from May 20 to July 1, during which period there was held back and impounded in reservoirs over 16,000,000,000 cubic feet of water, the flood waters of a drainage basin of 3265 square miles. This volume of water stored and held back from the floods below is sufficient to maintain a steady stream of 4630 cubic feet per second throughout the period named, while the discharge of the Mississipi at the mouth of the Sandy river at bank full stage is only about 4000 cubic feet per second. Had it not been for the holding back of this water in the reservoirs, the flood height between Sandy river and Aitkin would have been several feet higher than it was.

The reservoir of the Ottawa and French river water-sheds are much more extensive than three mentioned in the above report, and their advantages will be correspondingly greater.

OTTAWA RIVER WATERSHED.

The Ottawa river is one of the large rivers of the North American continent. Its source is almost directly north of the city of Ottawa. Its water-shed which, at Montreal, has an area of 56,000 square miles, is shown on Plate No. 3.

TRIBUTARIES.

For the amount of area tributary to the river, its length cannot be considered great. The water-shed is divided up into a number of drainage basins feeding into the river at regular intervals. On the north shore, these are the Du Nord, the Rouge, the Lievre, the Gatineau, the Coulonge, the Black, the Du Moine and Maganasibi. On the south shore, the La Graisse, Nation, Rideau, Mississippi, Madawaska, Bonnechere, Petawawa and numerous other smaller ones. All these rivers exist between Mattawa and Montreal. Above Mattawa are the Montreal and Kippewa rivers. Lake Temiskaming, which is often spoken of as the source of the Ottawa river, is a lake of an area of 115 square miles about 45 miles above Mattawa; but the main Ottawa enters Lake Temiskaming at the northern end after having come a distance of some 310 miles from a point almost directly north of the city of Ottawa. The river, therefore, forms three sides of a quadrilateral, but the water-shed is so divided by the tributaries that the drainage area of 56,000 square miles at Montreal is reduced to 12,100 square miles above the outlet of the Montreal river.

The drainage area of the river at different sections and of the main tributaries are as follows:—

—	Square Miles.	
Ottawa river above Montreal and Kippewa Rivers	12,106	
Montreal River	2,800	
Kippewa River	2,133	
Ottawa River valley between Mattawa and Montreal Rivers	1,744	
Mattawa River	880	
Ottawa valley between Deux Rivieres and Mattawa	225	
Maganasibi River	234	
Total to Deux Rivieres	....	20,122
Ottawa valley between Deux Rivieres and Rocher Capitaine	115	
Total to Rocher Capitaine	....	20,237
Du Moine River	1,517	
Ottawa valley between Rocher Capitaine and Des Joachims	394	
Total to Des Joachims	....	22,148
Schyan River	296	
Petawawa	1,586	
Indian River	440	
Ottawa valley between Des Joachims and Paquette	652	
Total to foot of Allumette Island	....	25,122
Black River	950	
Coulonge River	1,820	
Ottawa valley between Allumette and Calumet Islands	332	
Total to foot of Calumet Island	....	28,224
Ottawa valley between Calumet Island and Cheneaux	64	
Total to Cheneaux	....	28,288
Bonnechere River	910	
Madawaska River	3,210	
Mississippi River	1,400	
Ottawa valley between Cheneaux and Chats Falls	167	
Total to Chats Falls	....	33,975
Carp River	133	
Quion River	164	
Ottawa valley between Chats and the Chaudiere Falls	351	
Total to Chaudiere Falls	....	34,623
Rideau River	1,516	
Gatineau River	9,130	
Little Blanche River	137	
Ottawa valley between Chaudiere Falls and Besserers Grove	67	
Total to Besserers Grove	....	45,473
Du Lievre	4,043	
Blanche (Thurso)	236	
Nation River	1,436	
North Nation River	710	
Salmon River	78	
Rouge River	1,780	
Calumet River	163	
Ottawa valley between Besserers Grove and Grenville	408	
Total to Grenville	....	54,327
Ottawa valley between Grenville and Carillon	180	
Total to Carillon	....	54,507
North River	700	
La Graisse River	175	
Ottawa valley between Carillon and head of Montreal Island	311	
Total to head of Montreal Island	....	55,693
Total to mouth of Ottawa River	....	56,043

At one time the entire Ottawa river valley was covered with a pine and spruce forest, and about 95 per cent is still under forest. In general, the La Graisse, Nation, Rideau, Mississippi and the Bonnechere valleys are fairly well cultivated, the Madawaska at its outlet, and the other river valleys practically not at all.

INFORMATION PRIOR TO THE COMMENCEMENT OF THE SURVEY.

At the commencement of the survey it was decided to institute such investigations as were thought necessary to determine the effect of the improvements and changed conditions of the river. Practically no information had been collected of its hydraulics before this. Arrangements were made to tabulate all available data with respect to the present condition of the established water-power plants, as well as all other unused power along the canal route; to study the regime of the river, determining the discharge of the river and the principal effects of impounding surplus water in the spring in the upper portions of the water-shed.

So far as could be found, the only measurements in existence were those made by C. E. Gauvin, Supt. of Lands, Mines and Fisheries, which are particularly valuable for water-power development, as they give low water flow in winter at different sections. The results of those measurements are tabulated with those of this office in Table No. 1 at the end of this report. Also one measurement was made of the Ottawa by C. A. Biggar, C.E., and one set of gaugings at different stages of the river by the writer for Messrs. Kennedy of Montread some years ago. Some water levels at about five miles above Ottawa and those of the Department of Railways and Canals below Ottawa, and of the Gatineau river since 1899, obtained from Mr. Keefer, practically represented the entire existing data of not only the main Ottawa but the tributaries as well.

GAUGES.

Gauges were placed in the Ottawa river and in the principal feeders or tributaries in March and April 1905. One or two gauges were placed on each important reach. Below Ottawa, at the Rideau locks, the Department of Railways and Canals had kept records of the water level from 1844. Some of these are incomplete, but, in general, the information is reliable and sufficient.

In the tributaries, the gauges were placed in so far as possible so that they would not be affected by the back water from the Ottawa, but usually they were in mill-ponds where the water fluctuated with the opening and closing of the gates. Note of the condition of the gate openings was recorded so that a proper allowance could be made.

It was impossible to collect all the hydraulic data of the river, and the question was more to distinguish the most important portions, and how far the survey should go in the collection of other information.

In conjunction with the daily water level heights at different stages of the river, measurements of the quantity of water flowing to relate to these were commenced in the main Ottawa and in the tributaries. These measurements could not be made at all sections of the river where it was proposed to have improvements or where water levels were taken.

METERING SECTIONS SELECTED.

The following sections were selected for measurements of flow. One at Deux Rivieres; one at Coulonge; one below Ottawa at Besserers', and one above Montreal for each of the four branches. These sections were chosen both on account of their suitability for gauging and their position. In addition, gaugings were made of the tributaries, and from these and the corresponding gauges of the main Ottawa, it is possible to determine with sufficient accuracy for the purpose of a survey the discharge at each required section.

Some other gaugings were taken where the measurements on account of some particular feature of the river, was desired. The following method of measuring was adopted:—

METHOD OF METERING.

From the soundings taken in the winter, a section was selected where great regularity in the bottom existed and where the shores were parallel for some distance above and below, and where there were no cross currents. A base line was laid down on the shore, and by means of floats and two transits reading on these floats, the direction of the current at different points of the section of the river was found. If these directions, when plotted, were parallel, or nearly so, the gauging line was located perpendicular to the mean. In general, it was necessary to take the measurements of current velocity from a launch or large boat which was secured by two anchors up stream, and the distances were determined by transit intersections.

If the measurement located any undesirable feature, such as cross-currents, too high or too low a velocity for the meter, the section was rejected and a more suitable one chosen.

Soundings were taken of the depth, and two different methods of metering were followed—the Point method and the Six-tenths method. Two styles of meters were used—the Price and the Haskell-Ritchie, and interchanged. At the end of each week, these meters were rated at Britannia where a suitable rating station had been constructed. This rating was particularly necessary especially after the meters had been used for some days, as the wear incidental to contant use affects the rating.

ABSENCE OF EXTREME HIGH WATER MEASUREMENTS.

The measurements of the river were continued throughout the season of 1905. This reason was marked by no extreme fluctuations, either of high or of low water, and it was hoped in the spring of 1906 that high water might ensue so that a measurement of the quantity could be taken, but the spring of 1906 was again a low spring and was followed by an extremely low summer, as will be described later. The complete list of gaugings is given in Table I.

Since this report has been written, the spring and autumn of 1908 furnished an opportunity for the measurement of high or low water, and these measurements are inserted in the following lists.

The discharge curve at Besserer's Grove has been altered slightly to conform with the more complete data obtained during the spring of 1908.

The measurements taken in 1907 made the original curve appear to give too small discharges from elev. 131 upwards, hence note No. 2 was added to the daily discharge plates.

However, since the printing of these plates the river rose to a level not reached since the year 1899; in extending the curve to intersect the gaugings made at this higher level it was found to conform more closely to the original plotting, a slight variation occurring between elevations 130 and 138.

TABLE No. I.

Discharge Measurements of the Ottawa river at places mentioned.

THREE MILES BELOW VAUDREUIL, QUE.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
May 24	1905	135·75	29,879	117·35	....	
August 5	1905	130·12	3,861	....	....	
November 2	1905	129·26	6,779	....	....	
July 21	1906	130·41	7,940	....	....	
March 12-13	1907	126·56	15,190	....	....	Back water from the St. Lawrence.
May 30	1907	136·10	48,590	....	....	
June 17	1908	135·85	39,280	....	....	

STE. ANNE DE BELLEVUE.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
May 24	1905	135·75	41,399	117·35	....	
August 4	1905	130·12	12,336	....	....	
November 3	1905	129·26	13,415	....	....	
July 21	1906	130·41	11,841	....	....	
May 31	1907	136·10	50,781	....	....	
June 15	1908	136·35	42,917	....	....	

BACK RIVER.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
September 14	1903	128·68	26,882	....	....	Est'd., C. E. Gauvin, Que. Govt.
....	......	Low water.	20,000	....	....	" " "
May 22	1905	135·75	64,530	117·35	....	At Cartierville.
August 3	1905	130·12	34,767	....	....	"
November 4	1905	129·26	28,416	....	....	"
July 18	1906	130·41	34,657	....	....	"
May 31	1907	136·10	37,031	....	....	At Cap à L'Orme.
May 31	1907	136·10	35,000	....	....	Lallemand (estimated).
....	......	....	72,031	....	....	......Total for two channels.
September 2-6	1907	128·47	22,325	....	....	McGill College party.
June 20	1908	135·52	32,392	....	....	Head of Lallemand channel.
June 23	1908	134·93	32,579	....	....	Ste. Genevieve.
....	......	....	64,971	....	....	Total for two channels.

MILLE ILE RIVER.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
May 20	1905	135·75	17,559	117·35	....	At St. Eustache.
August 2	1905	130·12	3,486	....	....	"
November 6	1905	129·26	1,236	....	....	1½ miles above St. Eustache.
July 18	1906	130·41	2,862	....	....	From C.P.R. bridge at Rosemere.
June 1	1907	135·85	18,641	....	....	1½ miles above St. Eustache.
June 18	1908	135·68	17,011	....	....	C.P.R. bridge at Rosemere.

TOTALS FOR ABOVE FOUR BRANCHES.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
May 20-24	1905	135·75	153,367	117·35	55,700	
August 2-5	1905	130·12	54,450	....	....	
November 2-6	1905	129·26	49,846	....	....	
July 18-21	1906	130·41	57,300	....	....	

TOTALS AT MONTREAL.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
May 30-June 1	1907	135·97	190,043	....	....	
June 13-23	1908	135·62	164,179	....	....	

ABOVE CARILLON.

Date.	Year.	Water Level Gauge, Upper Grenville.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
May 29..........	1907	136·30	193,000	....	....	Above Carillon.
August 17.........	1907	129·63	47,500	....	....	"
September 14......	1907	128·52	33,044	....	....	"
June 13..........	1908	136·85	168,009	....	....	At Chute à Blondeau.

BESSERER'S GROVE.

Date.	Year.	Water Level Gauge	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
		Rideau Locks.		Rideau Locks.		
June 13..........	1904	145·80	182,000	....	....	Est'd., A. McDougall.
May 8..........	1905	136·97	74,531	122·47	45,473	
May 17..........	1905	139·64	116,000	....	....	
June 12-13........	1905	136·72	81,978	....	....	
July 4..........	1905	133·64	54,394	....	....	
July 28..........	1905	132·39	48,471	....	....	
September 6......	1905	130·06	25,540	....	....	
September 30......	1905	129·97	29,000	....	....	Est'd., J. B. McRae.
October 28........	1905	131·55	37,686	....	....	
May 17..........	1906	140·30	122,275	....	....	
September 11......	1906	128·51	18,746	....	....	
September 12......	1906	128·45	17,620	....	....	
October 13........	1906	128·00	15,600	....	....	
May 23..........	1907	142·00	142,468	....	....	
May 6..........	1908	144·09	160,433	....	....	
May 11..........	1908	146·13	185,719	....	....	
May 14..........	1908	147·13	198,660	....	....	
October 3.........	1908	127·72	14,610	....	....	

ABOVE OTTAWA.

Date.	Year.	Water Level Gauge	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
		Head of Deschenes Rapids.		Head of Deschenes Rapids.		
April..........	1900	190·07	20,842	187·47	34,623	Est'd., Biggar.
March 17-18.......	1904	189·39	11,500	....	....	Chaudiere owners, A. McDougall.
May 9-12.......	1904	196·72	129,454	....	....	" "
June 13..........	1904	197·26	145,118	....	....	" "
July 4-5..........	1904	194·64	78,864	....	....	" "
August 1-2........	1904	192·22	43,515	....	....	" "
August 10.........	1905	191·42	31,453	....	....	
September 30......	1905	190·97	23,000	....	....	J. B. McRae.
			Large Price Meter.			
September 17......	1906	189·89	12,200	....	....	1,000' below old burner, Skead's Mill.
			Haskell.			
September 18-19...	1906	189·81	13,250	....	....	
March 18-19.......	1907	189·67	14,016	....	....	At Besserer's and the Gatineau.
October 3.........	1908	189·79	11,200	....	....	Estimated from measurements.

PORTAGE DU FORT.

Date.	Year.	Water Level Gauge	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
			Portage Channel.			
September 13......	1900	2 ft. above L.W....	492	....	....	Que. Govt., C. E. Gauvin.

CALUMET CHANNEL.

Date.	Year.	Water Level Gauge	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
August..........	1900	3 ft. above L.W....	16,565	....	....	Ferry at Calumet vill., C. E. Gauvin, Que. Govt.
		Bryson.		Bryson.		
May 12..........	1905	346·04	26,711	340·34		4 miles above Campbells Bay.
November 16......	1905	342·39	10,925	....	....	" " "
....	.....	Low water.	8,000	....	....	Assumed, Grand Calumet Falls, C. E. Gauvin, Que. Govt.
June 17..........	1907	347·44	33,000	....	....	Ferry at Calumet Village.
May 16..........	1908	348·60	47,453	....	....	At Grand Marais ferry, float measurements.
May 18..........	1908	348·60	45,528	....	....	" " "
May 19..........	1908	348·50	46,266	....	....	" " "

GOWER POINT, ONT., TWO MILES BELOW FORT COULONGE.

Date.	Year.	Water Level Gauge.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
		Gower Pt.		Gower Pt.		
May 15	1905	350·21	62,905	343·41	27,900	
June 28	1905	347·66	44,341	....	....	
November 15	1905	344·26	22,628	....	....	
June 16	1907	352·26	95,150	....	....	
May 15	1908	353·85	124,838	....	....	Float measurements.
May 16	1908	354·00	124,703	....	....	" "
May 18	1908	354·05	131,267	....	....	" "
May 19	1908	353·95	128,754	....	....	" "
May 23	1908	353·80	126,824	....	....	" "

ONE MILE BELOW ALLUMETTE ISLAND

August 16	1905	344·76	20,014	343·41	26,072	
November 14	1905	344·31	16,095	....	....	
June 15	1907	352·32	90,911	....	....	

CULBUTE CHANNEL.

August 16	1905	344·76	2,791	343·41	....	
November 13	1905	344·46	3,020	....	....	
May 18	1905	350·21	4,304	....	....	From Chapeau bridge, C. E. Gauvin, Que. Govt.
May 31	1905	....	5,250	....	....	Floats.
June 14	1907	352·32	....	....	....	From Chapeau bridge.

DES JOACHIMS.

March	1901	Low water.	9,050	....	22,148	Est'd., C. E. Gauvin, Que. Govt.

ROCHER CAPITAINE.

March 14-16	1901	Low water.	8,400	....	20,237	Est'd., C. E. Gauvin, Que. Govt.

ABOVE DEUX RIVIERES.

		Klock.		Klock.		
May 15	1905	484·90	44,511	474·90	19,880	
				May 13, '06		
July 31	1905	480·15	22,058	480·56	....	
				July 8, '06	....	
October 6	1905	476·95	14,021	474·90	....	
May 11	1906	489·25	67,155	....	....	
June 12	1907	491·06	77,100	....	....	
May 19	1908	490·51	75,009	....	....	
May 20	1908	490·66	75,448	....	....	
May 22	1908	490·86	78,085	....	....	
June 1	1908	491,96	83,248	....	....	
June 10	1908	491·66	81,641	....	....	
June 17	1908	490·56	75,795	....	....	

MATTAWA.

March 30	1901	Nearly its lowest pitch	8,225	....	19,663	From Ry. bridge, C. E. Gauvin, Que. Govt.

SIX MILES ABOVE MATTAWA.

March	1901	....	7,800	....	18,700	Ass'd., C. E. Gauvin, Que. Govt.

LES ERABLES RAPIDS.

Date.	Year.	Water Level Gauge,	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
March	1901	Low water.	7,700	....	....	Est'd., C. E. Gauvin, Que. Govt.

LONG SAULT RAPIDS.

Date.	Year.	Water Level Gauge,	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
March	1901	Low water.	6,500	....	18,060	Est'd., C. E. Gauvin, Que. Govt.

GAUGINGS AT THE CHAUDIERE.

	Date.	Elevations.		Discharge, cub. ft. per second.	Remarks.
		Head.	Foot.		
	1905.				
Waterworks aqueduct	June 21	168·57	144·57	682	
Ottawa & Hull P. Co., head race	July 11	....	....	....	10 to 1 p.m.
Ottawa Electric Co. No. 1 head race	" 11	....	....	....	3 p.m. to 5.30 p.m.; cancelled.
Ottawa Electric Co., No. 1 head race	" 12	165·27	136·07	1,089	3 p.m. to 5 p.m.; mat worked out, leakage.
Bronsons' head race	" 14	164·55	140·40	543	Above rack.
Ottawa Investment Co	" 14	164·55	140·40	519	Below rack.
Bronsons' head race	" 15	....	....	971	9.20 a.m. to 11 a.m.
Ottawa Street Railway	" 17	....	....	274	5.10 p.m. to 6.15 p.m.
Ottawa & Hull Power Co	" 20	....	....	....	1 p.m. to 3 p.m.; 1 wheel running.
Ottawa & Hull Power Co	" 20	169·12	135·48	1,560	4 p.m. to 5 p.m.; 2 wheels running.
J. R. Booth's head race; saw mill	" 22	169·40	....	2,591	
J. R. Booth's pulp mill tail race	" 24	....	....	3,716	Soundings made on Sunday; water quiet.
North slide	" 25	....	....	412	Float measurement.
E. B. Eddy's bulkhead	" 25	....	....	5,078	
Ottawa Street Railway Co	Aug. 18	163·54	140·40	934	3.45 p.m.
Ottawa Electric Co., No. 1 P. house	" 19	163·74	136·06	928	10.30 a.m.
Bronson's head race	" 19	163·74	136·33	984	1.30 p.m. to 2.30 p.m.
Ottawa Investment Co., Canada Saw Works	" 19	....	....	....	3 p.m.; cancelled.
J. R. Booth's pulp mill tail race	" 21	162·11	140·08	3,501	9 a.m. to 10.15 a.m.
J. R. Booth's saw mill head race	" 21	168·77	....	3,574	
Consumers Elect., Ottawa & H. P. Co.	" 21	168·31	136·30	1,555	4 p.m. to 5.30 p.m.
E. B. Eddy's bulkhead	" 22	166·84	135·20	4,098	9.30 a.m.
E. B. Eddy's saw works	" 22	....	....	....	1.30 p.m. to 2.30 p.m.; cancelled; water ch'gd
Waterworks channel	" 22	169·02	....	541	
	1906.				
J. R. Booth's saw mill head race	Sept. 27	164·57	....	2,421	7 a.m.
J. R. Booth's pulp mill tail race	" 27	....	....	1,372	10.15 a.m.; float measurement.
Buchannan channel	Oct. 2	....	....	2,104	2.20 p.m.
Ottawa Street Railway	" 2	....	....	554	
No. 2 power house bulkhead	" 2	....	....	1,256	4.50 to 5.07 p.m.
J. R. Booth's head race saw mill	" 3	164·74	....	1,908	8.15 to 9.20 a.m.
J. R. Booth's head race saw mill	" 3	164·47	....	1,772	2.45 to 3.57 p.m.
J. R. Booth's head race saw mill	" 5	165·27	....	1.757	9.50 p.m.
Bronson's head race	" 6	160·86	128·30	602	2.40 to 3 p.m.
Ottawa Street Railway power house	" 6	No elev.	....	482	3.40 to 4.05 p.m.
Power house, No. 1 head race	" 6	164·28	137·11	1,215	4.30 to 4.55 p.m.
Bronson's head race	" 8	161·85	133·35	690	9.50 to 10.15 a.m.
Ottawa Electric Co., P.H. No. 1	" 8	161·58	135·31	575	10.50 to 11.25 a.m.
Ottawa Street Railway tail race	" 8	163·92	140·69	665	3 p.m.
No. 2 power house race	" 8	165·92	....	1,032	3.25 to 4.15 p.m.
J. R. Booth's saw mill head race	" 9	164·97	....	2,205	8.40 to 10.10 a.m.
No. 2 power house head race	" 9	165·27	....	1,132	11.20 a.m.
No. 2 power house head race	" 10	165·38	....	1,085	9.50 to 10.25 a.m.
No. 2 power house head race	" 10	165·77	....	1,189	2.20 p.m. Estimated, added increased area.
Ottawa Street Ry., from bulkhead	" 10	165·27	....	577	10.45 to 11.22 a.m.
Ottawa Street Ry., from bulkhead	" 10	166·27	....	702	Estimated, added increased area.
Buchannan channel	" 10	166·32	....	1,145	2.40 to 3.14 p.m.
J. R. Booth's saw mill head race	Nov. 19	167·12	....	2,448	2 p.m. to 2.50 p.m.
Buchannan channel	" 19	167·12	....	2,598	3.10 p.m.
Ottawa Street Railway bulkhead	" 19	167·12	....	1,842	3.55 p.m.
No. 2 power house	" 19	167·12	....	1,239	

Discharge Measurements of the Ottawa River and Tributaries at places mentioned.

RIVER DU NORD.

Date.	Year.	Water Level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. mile.	Remarks.
Jan. 19....	1905	....	250	....	455	Saunderson's rapids, estimated. Mr Leveille.
June 3....	1905	94·23	883	Ass'd 89·41	700	2½ miles. W. of St. Andrews, Que.
		low water.	233	....	455	Mr. Leveille.
Aug. 15....	1907	93·92	434	....	....	2½ miles above St. Andrews, Que.
Sept. 13....	1907	93·70	387	....	....	2½ miles above St. Andrews, Que.

RIVER ROUGE.

Date.	Year.	Water Level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. mile.	Remarks.
				Ass'd 84·93	1,780	6 miles north of Calumet, P.Q.
Mar. 21....	1905	....	847	....	....	Wm. Kennedy, jr.
June 1....	1905	90·33	4,277	....	....	1 mile above Ross's power house.
Aug. 11....	1905	88·93	1,855	....	....	
		Ex. low.	750	....	....	See Wm. Kennedy's letter, Feb. 13, 1906.—Pringle.
May 29.....	1908	91·43	12,163	....	....	Johnston's ferry.

NORTH NATION RIVER.

Date.	Year.	Water Level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. mile.	Remarks.
				Ass'd 87·52	710	½ mile west of Plaisance, Que.
Nov. 8–9....	1901	about the lowest L.	237	....	....	At the Oxbow falls.
June 1....	1905	92·82	1,546	....	....	
Aug. 11....	1905	91·72	1,320	....	....	
May 28....	1908	93·72	3,649	....	....	

BLANCHE RIVER—(Big Blanche).

Date.	Year.	Water Level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. mile.	Remarks.
				Ass'd 100·00	236	3 miles west of Thurso station, Que.
May 31....	1905	103·0	186	....	....	
Aug. 10....	1905	100·81	197	....	....	
May 27....	1908	101·2	449	....	....	Lower dam out.

RIVER DU LIEVRE.

Date.	Year.	Water Level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. mile.	Remarks.
				Ass'd 85·71	4,043	
April 6....	1896	....	2,500	....	....	J. Kennedy.
April 2....	1901	....	2,042	....	....	Just above High falls. (*See* Wm. Kennedy's letter, February 6.
Sept. 24....	1902	....	1,487	....	2,204	1st range Tp. of Campbell, Dept of L. M. & F. C. E. Gauvin.
Feb. 25....	1905	....	1,725	....	....	Price Accoustic meter through ice. Mr. Farlay.
May 30....	1905	91·61	12,456	....	....	
Aug. 10....	1905	88·86	1,907	....	....	
Nov. 7....	1905	90·01	3,734	....	....	
May 21....	1908	....	27,588	....	....	Float measurement.

RIVER BLANCHE—(Little Blanche).

Date.	Year.	Water Level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. mile.	Remarks.
				Ass'd 93·43	137	2 miles east of East Templeton, Que.
May 29....	1905	97·23	261	....	....	
Aug. 9....	1905	96·63	36	....	....	

GATINEAU RIVER.

Date.	Year.	Water level gauge.	Discharge, cub. ft. per second.	Elevation, zero of gauge.	Drainage area, sq. miles.	Remarks.
				Ab. M.S.L. Zero.		
Sept. 30....	1902	....	3,887	....	....	Estimated from Maniwaki gauges.
		E.L.W.	3,000	....	....	Estimated from Maniwaki gauges.
Oct. 7...	1902	2 f. ab.L.W	{ 3,375	....	....	East channel 1500′ below Maniwaki bridge.
			875	....	....	West channel, Dept. L.M. & F.
			4,250	....	....	Total, C. Gauvin, Que.
Oct. 14....	1902	....	5,240	....	....	Dept. L.M. & F., Que., at bridge between Hull and Gatineau Point.
May 18....	1905	212·49	35,103	205·66 Changed Aug. 14 to	9,130	Chelsea.
June 10....	1905	208·91	19,863	203·66	....	Chelsea.
July 3....	1905	206·74	11,565	....	....	Chelsea.
July 27....	1905	206·24	9,317	....	....	Chelsea.
Sept. 2....	1905	204·86	4,897	....	....	
Oct. 25....	1905	206·56	10,256	....	....	At mouth.
Oct. 27....	1905	206·66	12,546	....	....	At mouth.
Nov. 2....	1905	206·06	10,543	....	....	J. B. McRae.
May 15....	1906	210·5	32,442	....	....	Above Ironsides.
Oct. 15....	1906	204·66	5,578	....	....	Above Ironsides.
May 25....	1907	212·71	45,594	....	....	Above Ironsides.
Aug. 29....	1907	....	....	....	....	Gens de Terre river, ½ mile above mouth.
" 29....	1907	....	....	....	....	3½ miles above mouth of Gens de Terre river.
Aug. 31....	1907	....	....	....	....	Desert river, above bridge at Maniwaki.
May 7....	1908	213·16	47,920	....	....	Above Ironsides.
" 12....	1908	214·46	58,459	....	....	Above Ironsides.
" 15....	1908	214·67	63,542	....	....	Above Ironsides.
Sept. 30....	1908	203·96	3,304	....	....	Above Ironsides.

QUYON.

May 30..........	1905	105·10	208	Ass'd. 100·00	164	

COULONGE.

May 31..........	1905	105·30	6,466	Ass'd. 100·00	1,820	
June 29..........	1905	104·40	3,143	....	....	
August 15........	1905	103·40	1,481	....	....	
November 14......	1905	103·70	1,702	....	....	
May 20..........	1908	108·70	14,868	....	....	Float measurements.
May 26..........	1908	108·50	11,633	....	....	" "
May 26..........	1908	108·50	11,636	....	....	" "

BLACK.

May 31..........	1905	104·43	3,998	Ass'd. 100·00	950	At Waltham, Que.
June 29..........	1905	103·64	1,858	....	....	
August 15........	1905	102·40	547	....	....	
November 13......	1905	102·89	816	....	....	
June 15..........	1907	104·17	....	....	....	
May 21..........	1908	105·70	7,411	....	....	Floats.
May 22..........	1908	105·50	6,710	....	....	"

DUMOINE.

June 2..........	1905	103·80	4,000	Ass'd. 100·00	1,517	
August 2........	1905	101·02	1,926	....	....	
October 5........	1905	98·85	672	....	....	
May 28..........	1908	105·98	....	....	....	

MAGANASIBI.

Date.	Year.	Water Level Gauge.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
				Ass'd. 100·00	234	
June 1	1905	102·23	621			
August 1	1905	101·55	188			
October 7	1905	101·02	76			
May 12	1906	102·45	782			
June 12	1907	102·34	699			
May 21	1908	102·84				
May 29	1908	102·38				

KIPPEWA.

					2,133	
March 22	1902	Low water.	603			Approx. at outlet to lake. C. E Gauvin.
March 24	1902	Low water.	43			Gordon creek. C. E. Gauvin.
			646			Total low water flow from lake. C. E. Gauvin.

LA GRAISSE.

				Ass'd. March 29 85·57	175	
April 5	1905	92·55	1,997	April 15 86·55		
June 7	1905	89·34	28	Aug. 31 84·80		

NATION.

March 30	1905	95·64	17,708	Ass'd. 88·49	1,436	Near Plantagenet, Ont.
June 8	1905	91·28	176			
May 23	1908	Gauge out.	1,016			

RIDEAU.

				No lev. to zero.	1,516	
April 1	1901	No gauge.	14,300			Andrew Bell, C.E.
April 20-21	1905	2·77	2,365			
June 6	1905	1·40	391			
August 14	1905	1·70	705			
May 13	1908	Gauge out.	9,409			

MISSISSIPPI.

April 8	1905	91·99	7,755	Ass'd. 87·69	1,400	Near Galetta, Ont.
June 14	1905	89·48	2,005			
August 5	1905	88·74	666·3			Highway bridge, S. channel.
August 5	1905	88·74	709·4			" " N. "
			1,376			Total.
October 3	1905	88·06	695			
March 30	1906		700			High Falls. J. B. McRae.
May 20	1908		2,862			

MADAWASKA.

Date.	Year.	Water Level Gauge.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
				Ab. M.S.L. 253·15	3,210	At Wallace bridge, 8 miles W.
September 12	1898	....	1,174	....	....	Note.—From McLachlins. W. L. Scott, C.E.
April 14	1905	257·15	7,904	....	....	
April 25	1905	256·73	6,362	....	....	
June 15	1905	257·88	5,841	....	....	
August 5	1905	257·65	4,866	....	....	
May 19	1908	259·15	18,222	....	....	
July 15	1908	256·10	2,730	....	....	
September 8	1908	251·15	500	....	....	Estimated.

BONNECHERE.

				No levels to gauge.	910	
April 26	1905	1·65	1,771	....	....	At C.P.R. bridge, Renfrew.
June 16	1905	1·50	1,613	....	....	
August 4	1905	0·70	812	....	....	
May 19	1908	....	3,901	....	....	

MUSKRAT.

				Ass'd. 88·94	440	Pembroke.
April 28	1905	97·19	402	....	....	
June 16	1905	97.14	441	....	....	
August 4	1905	93·62	200	....	....	

PETAWAWA.

				Ass'd. 100·00	1,586	
April 27	1905	100·90	1,864	....	....	
June 17	1905	102·36	4,000	....	....	
August 3	1905	101·35	2,647	....	....	
October 4	1905	99·60	606	....	....	
May 18	1908	103·70	6,994	....	....	

MATTAWA RIVER AT MATTAWA.

				Ass'd. 490·27	880	
April 14	1905	11·60	2,005	....	....	
May 30	1905	9·50	2,385	....	....	
August 28	1905	....	383	....	....	Talon dam closed, August 26.
December 5	1905	....	419	....	....	
June 18	1907	....	....	....	....	
May 27	1908	....	....	....	....	

BOOM CREEK.

April 15	1905	....	191	....	....	

DEPOT CREEK.

April 12	1905	....	56	....	....	

WISTAWASA CREEK.

April 13	1905	3·90	15	....	52·5	

SUMMIT WATERS.

Lake Nasbonsing Outflow.

MENARD'S BRIDGE.

Date.	Year.	Water Level Gauge,	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
				Menard's.	At Menard's Bridge.	
March 3	1905	679·57	19·45	676·32	71·5	Gauge made through ice 3 ft. thick.
April 6	1905	679·29	148·			
April 6	1905	679·29	146·			
April 7	1905	679·21	140·			
April 7	1905	679·21	143·			
April 12	1905	679·24	129·			Dammed by logs.
April 12	1905	679·24	128·			" "
April 19	1905	679·10	116·			
April 19	1905	679·10	99·			
April 19	1905	679·10	110·			
April 19	1905	679·10	116·			
April 26	1905	679·00	99·			
April 26	1905	679·00	96·			
April 26	1905	679·00	96·			
April 29	1905	679·03	109·			
April 29	1905	679·03	116·			
May 10	1905	679·35	150·			Red Rapids.
May 18	1905	679·52	169·			
May 18	1905	679·52	169·			
May 24	1905	679·12	114·			
May 24	1905	679·12	118·			
May 29	1905	681·52	598·			Dam open.
May 29	1905	681·62	612·			"
May 29	1905	681·92	718·			"
May 29	1905	681·82	703·			"
May 31	1905	678·82	79·			Dam closed.
May 31	1905	678·82	77·			"
May 31	1905	678·82	327·			Dam open.
May 31	1905	680·32	408·			"
May 31	1905	680·72	492·			"
June 14	1905	678·97	151·			Red Rapids.
June 14	1905		95·			
June 14	1905	678·97	111·			

TURTLE LAKE.

Date.	Year.	Water Level Gauge,	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
					Fr. Whitefish Bay.	
March 8	1905	641·13	42	639·1	78	Gauging made at outlet of Whitefish Bay.
March 30	1905	641·28	70			" "
March 30	1905	641·28	68			" "
April 6	1905	641·56	113			" "
April 6	1905	641·56	113			" "
April 7	1905	641·43	105			" "
April 7	1905	641·43	102			" "
April 18	1905	642·15	91			" "
						Low volume due to logs jamming in creek.
May 17	1905	643·51	335			Gauging made at outlet of Whitefish Bay.
May 17	1905	643·51	444			Logs below section.
May 24	1905	642·21	187			Logs cleared.
May 24	1905	642·21	187			

LAKE TALON.

Date.	Year.	Water Level Gauge.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
		Pimisi.		Pimisi.		
February 25	1905	583·97	255.	582·21	342	Section not suitable.
February 27	1905	583·94	245·	....	....	" "
February 28	1905	583·92	259·	....	....	" "
March 11	1905	584·10	200·	....	....	Talon Chute Narrows.
March 14	1905	584·08	197·	....	....	Below gauge below Pimisi.
March 14	1905	584·08	200·	....	....	" " "
March 27	1905	584·46	337·	....	....	Talon Chute Narrows.
March 27	1905	584·46	357·	....	....	" "
March 28	1905	584·49	304·	....	....	" "
April 5	1905	585·51	680·	....	....	" "
April 5	1905	585·51	658·	....	....	" "
April 10	1905	585·66	878·	....	....	" "
April 10	1905	585·66	721·	....	....	" "
April 10	1905	585·66	859·	....	....	" "
April 11	1905	585·69	875·	....	....	" "
April 11	1907	585·69	856·	....	....	" "
April 17	1905	585·76	918·	....	....	" "
April 17	1905	585·76	901·	....	....	" "
April 25	1905	587·20	253·	....	....	Talon dam closed 10 a.m., April 19.
April 25	1905	587·20	254·	....	....	Talon Chute Narrows.
April 26	1905	584·22	202·	....	....	" "
April 26	1905	584·22	220·	....	....	" "
May 1	1905	584·78	427·	....	....	" "
May 1	1905	584·78	468·	....	....	" "
May 2	1905	584·81	496·	....	....	" "
May 4	1905	585·77	601·	....	....	" "
May 4	1905	585·77	613·	....	....	" "
May 6	1905	585·23	626·	....	....	" "
May 6	1905	585·23	592·	....	....	" "
May 9	1905	585·52	736·	....	....	" "
May 9	1905	585·52	828·	....	....	" "
May 13	1905	585·41	751·	....	....	" "
May 13	1905	585·41	670·	....	....	" "
May 16	1905	585·43	704·	....	....	" "
May 16	1905	585·43	697·	....	....	" "
May 22	1905	585·81	849·	....	....	" "
May 22	1905	585·81	902·	....	....	" "
June 6	1905	586·11	918·	....	....	Dammed by logs.
June 10	1905	585·59	312·	....	....	Taken through logs; unreliable.
June 12	1905	585·68	220·	....	....	Dammed by logs.
June 16	1905	586·23	1,150·	....	....	Talon Chute Narrows.
June 16	1905	586·23	1,099·	....	....	See letter of June 29.
June 23	1905	586·21	1,186·	....	....	Talon Chute Narrows.
June 23	1905	586·21	1,098	....	....	" "
July 13	1905	583·41	65·	....	....	150′ below gauge below Pimisi.
August 25	1905	584·29	135·	....	....	Pimisi dam opened; Talon dam closed.
August 26	1905	584·11	173·	....	....	Pimisi dam opened; one gate Talon dam closed.
July 17	1906	584·19	222·	....	....	Talon dam closed.

AMABLE DU FOND RIVER (Flowing into the Mattawa).

Date.	Year.	Water Level Gauge, Camerons.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
				749·22	433	
May 12	1905		627·			1½ mile below Eau Claire.
May 12	1905		597·			" "
May 12	1905		300·			Estimated Patois river.
June 24	1905		456·			Dams at Booth's farm closed Jan. 16.
June 29	1905		421·			" " "
July 14	1905	753·90	635·			Ab. Chute de Bully-dam at Kioskoka opened, 3 logs.
August 29	1905	751·82	165·			Above Chute de Bully.
September 14	1905	752·	218·			" "
September 28	1905	757·62	195·			" "
December 8	1905	751·82	287·			Booth's farm, taken at gauge.
December 8	1905	751·82	281·			200′ above gauge at Camerons.
December 8	1905	751·82	269·			¼ mile above gauge.
December 9	1905	751·72	237·			At Kioshkoqui.
December 9	1905	751·72	253·			At Kioshkoqui, small side channel.
December 28	1905	752·02	247·			Camerons.
March 2	1906	752·32	184·			240′ above Camerons 6-10 method-ice 9″.
March 2	1906	752·32	168·			240′ above Camerons—Point method.
		752·82	208·			
April 27	1906	753·02	457·			
April 27	1906	753·59	553·			
April 27	1906	753·20	485·			
April 28	1906	752·64	368·			
April 28	1906	752·62	376·			
May 1	1906	753·57	542·			
May 1	1906	753·56	603·			
May 1	1906	753·96	624·			
May 1	1906	754·36	724·			
May 1	1906	754·56	809·			
May 1	1906	754·22	809·			
May 2	1906	753·72	483·			
May 2	1906	753·99	532·			Logs.
May 3	1906	756·35	1,071·			"
May 3	1906	756·47	1,019·			"
May 3	1906	756·54	1,108·			"
May 3	1906	756·51	966·			"
May 4	1906	756·385	967·			"
May 5	1906	756·435	961·			"
May 8	1906	755·365	977·			Some logs
May 8	1906	755·13	954·			"
May 9	1906	755·17	870·			"
May 9	1906	754·735	850·			"
May 9	1906	754·685	846·			"
May 10	1906	754·67	864·			
May 10	1906	754·71	933·			
May 11	1906	754·655	806·			
May 12	1906	754·61	865·			
May 17	1906	754·71	909·			
May 18	1906	754·79	835·			
May 19	1906	754·57	812·			
May 19	1906	754·765	860·			
May 21	1906	754·95	931·			
May 21	1906	754·89	860·			
May 22	1906	754·985	1,003·			
May 22	1906	754·995	969·			
May 22	1906	754·905	938·			
May 22	1906	754·89	965·			
May 23	1906	754·725	949·			
May 23	1906	754·81	980·			
May 23	1906	754·985	1,008·			
May 23	1906	755·13	1,016·			
May 24	1906	755·075	1,011·			
May 24	1906	755·49	1,064·			
May 25	1906	755·12	984·			
May 25	1906	754·96	917·			
May 25	1906	5·635	883·			
May 25	1906	5·60	908·			
May 26	1906	6·20	1,087·			
May 29	1906	6·10	1,127·			
May 29	1906	6·10	1,123·			
May 29	1906	6·03	1,126·			
May 29	1906	6·03	1,125·			
May 30	1906	5·96	1,101·			

AMABLE DU FOND RIVER—(Flowing into the Mattawa)—*Continued.*

Date.	Year.	Water Level Gauge, Camerons.	Discharge, cub. ft. per second.	Elev. Zero of Gauge.	Drainage Area, sq. miles.	Remarks.
			1,126·P.M			
May 31	1906	6·00	1,091$\frac{6}{10}$			
May 31	1906	6·00	1,091·			
May 31	1906	5·92	1,132·			
May 31	1906	5·92	1,134·			
June 1	1906	5·81	1,086·			
June 1	1906	5·80	992·			
June 1	1906	5·80	1,067·			
June 1	1906	5·77	1,069·			
			1,067·			
June 1	1906	5·77	1,085·			
June 2	1906	5·62	1,008·			
June 2	1906	5·62	1,008·			20′ below gauge at Camerons.
June 4	1906	5·99	1,124·			½ mile below Brennan's rapids.
June 4	1906	6·00	1,210·			
June 4	1906	6·00	1,122·			
June 4	1906	6·00	1,131·			
June 5	1906	6·00	1,205·			
June 5	1906	6·00	1,197·			20′ below gauge at Camerons.
June 5	1906	6·00	1,167·			" " "
June 6	1906	6·00	1,057·			" " "
June 6	1906	6·00	1,130·			½ mile above Brennan's rapids.
June 6	1906	6·00	1,124·			Point method.
			1,140·			6-10 method.
June 6	1906	5·97	1,174·			
June 7	1906	5·80	1,076·			
June 7	1906	5·80	1,059·			
June 7	1906	5·80	1,001·			
June 7	1906	5·79	1,050·			
June 7	1906	5·71	1,047·			
June 8	1906	6·02	1,262·			
June 18	1906	2·50	285·			
June 18	1906	2·50	286·			
June 21	1906	5·97	1,150·			
June 21	1906	5·87	1,105·			
June 22	1906	5·62	1,008·			
June 22	1906	5·55	1,006·			
June 23	1906	5·38	1,019·			
June 25	1906	2·61	301·			
June 25	1906	2·60	291·			
June 27	1906	5·03	878·			
June 27	1906	5·00	869·			
June 28	1906	4·95	830·			
June 29	1906	4·74	775·			
June 29	1906	4·70	780·			
June 29	1906	4·68	765·			
June 30	1906	4·57	739·			
July 3	1906	2·50	266·			
July 3	1906	3·19	445·			
July 3	1906	3·48	504·			
July 3	1906	3·87	584·			
July 3	1906	3·98	622·			
July 4	1906	4·55	729·			
July 5	1906	4·37	692·			
July 5	1906	4·27	604·			
July 6	1906	4·17	556·			
July 13	1906	1·62	179·			
July 14	1906	1·62	176·			
		Manitou L.				
January 8	1906	1·73				Outlet to Manitou lake.
January 5	1906					" Mink lake.
January 9	1906	3 mile L.				" Tea lake.
January 11	1906	0·6				" 3 mile lake.
January 10						Indian river.

Lake Nipissing Waters.

FRENCH RIVER.

Elevation 648·0 proposed level of Lake Nipissing.
Zero of gauge on dam .... =642·23
Elevation B.M. 643·69 at point about ¾ mile above the Big Chaudiere....

Drainage area of the French river...... 6,900
" " Lake Nipissing........ 4,077
Zero of gauge at North Bay............ =637·70

Date.	Elevation of Water Surface.		Discharge.	Remarks.
	North Bay.	French River.		
			c. f. s.	
1905.				
September 15.....	638·7	....	3,760	Big Chaudiere.
September 16.....	....	....	240	East branch, Little Chaudiere.
September 16.....	....	....	1,005	West branch, Little Chaudiere
			5,005	Total flow.
October 19.......	638·35	....	3,503	Big Chaudiere.
October 20.......	....	....	204	East Little Chaudiere.
October 20.......	....	....	866	West "
			4,573	Total flow.
1906.				
August 9.........	640·66	....	4,069	Big Chaudiere. Strong west wind, 9th to 15th.
August 10........	....	....	518	East Litttle Chaudiere.
August 10........	....	....	2,060	West Little Chaudiere.
			6,647	Total.
August 18........	....	....	4,648	Bad river, east side.
August 19........	....	....	965	" centre channel.
August 19........	....	....	246	" west "
August 20........	....	....	403	" " "
			6,262	Total flow of the Bad river.
August 21........	....	....	2,032	Main channel, ¾ mile above tramway.
			8,294	Total flow of French river.
1907.				
May 30...........	641·85	641·88	4,433	Big Chaudiere, southeast wind.
May 31...........	....	....	607	East Little Chaudiere.
May 31...........	....	....	2,612	West Little Chaudiere.
			7,652	Total.
June 7...........	....	....	3,264	Bad river channel. (1).
June 6...........	....	....	8,580	" " (2).
June 7...........	....	....	1,555	" " (3).
June 7...........	....	....	2,065	" " (4).
			15,464	Total flow of Bad river.
June 8...........	....	....	4,681	Main channel, ¾ mile above tramway.
June 8...........	....	....	513	Bass channel
June 8...........	....	....	138	East outlet, east channel.
			354	West " "
			21,150	Total flow of French river.
June 21..........	642·72	642·74	5,133	Big Chaudiere, east.
June 21..........	642·72	642·74	5,133	Big Chaudiere, east.
June 21..........	....	....	869	East Little Chaudiere.
June 21..........	....	....	3,483	West "
			9,485	Total

FRENCH RIVER—*Continued.*

Elevation 648·0 proposed level of Lake Nipissing.
Zero of gauge on dam..... .... = 642·23
Elevation B.M. 643·69 at point about ¾ mile above the Big Chaudiere.

Drainage area of the French river....... 6,900
" " Lake Nipissing... 4,077
Zero of gauge at North Bay............ = 637·70

Date.	Elevation of Water Surface. North Bay.	Elevation of Water Surface. French River.	Discharge.	Remarks.
1905.			c. f. s.	
September 6......	640·29	640·30	3226	Big Chandiere; mostly calm.
September 7......	....	....	463	Big Chaudiere; mostly calm, light east wind. East Little Chaudiere.
September 7......	....	....	1,364	West "
			5,053	Total.
Estimated high water flow......		....	6,870	Big Chaudiere, northwest estimated.
			1,510	East Little Chaudiere, estimated.
			5,010	West " "
			13,390	Total.
May 25...........	644·23	644·26	5,585	Big Chaudiere.
			996	East branch, Little Chaudiere.
			330	West " " "
			6,911	Total. 267 main dam, Little Chaudiere. 150 leakage. 317
			148	North opening, dam at Big Chaudiere.
			122	South " " "
			4,600	Log channel.
			4,920	Total +50 c. f. s. for leakage.
June 12..........	644·70	644·62	5,516	Big Chaudiere; west winds.
			1,082	East branch, Little Chaudiere.
			467	West " " "
			7,065	Total. 296 main dam, Little Chaudiere. 55 leakage. 351
June 12..........	644·70	644·62	170	North opening, dam at Big Chaudiere.
June 12..........	....	....	142	South " " "
June 12..........	....	....	5,187	Log channel.
			5,549	Total, Big Chaudiere + 50 c. f. s.

From the water level at the time the different measurements were taken, the discharge curve was plotted for each section.

The results of these measurements give the discharge of the low and ordinary stages of the river with fair accuracy. As previously mentioned, at none of the sections did extreme high water occur during the two years of the survey. In 1904, however, when the water was extremely high, measurements as shown in Table No. 1 were taken above Ottawa in connection with other surveys and these results were used to find the high water of other sections by relation and an extension of the discharge curve for the individual sections.

The most complete set of records of fluctuations of the river are those at the foot of the Rideau locks. These records extend from 1844 to the present date, with some few exceptions. More information with reference to the flow at the different elevations of the gauge was collected for this portion of the river than for any other, as it was deemed wiser to have more complete information for one particular section which could be related to the others rather than have the data spread out over the entire river but lacking the extended nature of the gaugings of the Rideau locks.

RIDEAU LOCKS GAUGE AND FLOW MEASURED AT BESSERER'S GROVE.

This gauge shows the level of the water in the reach below the city of Ottawa. Uninterrupted navigation exists from the City of Ottawa down to Grenville, a distance of about sixty miles, and no great break occurs in the slope throughout the entire distance. At several places, owing to the restricted channel, swift currents exist. The level of the water, therefore, at the Rideau locks is affected both by the quantity of water flowing in from the main Ottawa above the Chaudière falls and also by that of the tributaries which enter into this reach, the principal ones being the Gatineau, the Lievre, the Rouge, the Nation and the Rideau. Any fluctuations in these tributaries will affect the water level at the Rideau locks, and the wind will also considerably affect it. In the winter time, this gauge, in common with many other gauges along the route, is somewhat affected by ice conditions. The quantity of water was measured at Besserer's Grove, some nine miles below Ottawa, and seven miles below the mouth of the Gatineau. From these measurements the discharge curve, as shown on Plate No. 26, was plotted. From the measurement of 1904, taken above Ottawa at extreme high water, the corresponding discharge of the Gatineau, records of which have been obtained from December 12, 1899, the discharge at Besserer's Grove for the high water of 1904 was estimated, and the discharge curve extended to this point. The gauge height at the Rideau locks shows that about every five years the river rises to the height reached in 1904.

The record high water is held by the rise in the year 1876 to elevation 151·97 on the Rideau lock gauge, which is 11·84 feet higher than in the year 1905, and 5·92 feet higher than the water of 1904, and twenty-five feet higher than the record low water of 1846.

The corresponding fluctuations of flow and water level at other sections are as follows:—

Tables of highest and lowest recorded waters on the Ottawa River at places mentioned.

STE. ANNE.

Year.	Upper Lock. Highest.	Date.	Upper Lock. Lowest.	Date.	Lower Lock. Highest.	Date.	Lower Lock. Lowest.	Date.
1870	78·32	April 27	68·40	Oct. 16	75·13	April 27	68·62	Sept. 29
1871	76·82	May 9	68·27	" 2	73·62	May 9	67·38	Nov 14
1872	75·90	May 18	69·40	Sept. 5	71·80	" 18	67·55	Sept. 3
1873	77·90	June 1	69·32	" 19	73·97	" 30	68·22	" 17
1874	76·32	May 26	68·57	Oct. 2	73·30	" 24	67·72	Nov. 7
1875	79·06	" 20	70·23	" 1	73·80	" 20	67·88	Oct. 2
1876	81·07	" 15	69·82	Sept. 15	76·63	" 16	68·72	Sept. 18
1877	74·15	" 1	69·40	" 24	71·97	Mar. 29	67·55	Oct. 22
1878	74·07	" 15	70·70	" 13	71·80	May 18	68·72	Sept. 11
1879	78·82	" 22	69·82	Nov. 8	74·22	" 21	67·47	Nov. 8
1880	78·23	" 19	70·23	Oct. 1	73·72	" 19	68·05	Sept. 24
1881	76·40	" 21	69·07	Sept. 16	72·22	" 21	67·54	" 22
1882	76·73	June 5	71·40	Oct. 19	72·97	June 5	68·30	Nov. 30
1883	76·07	" 1	71·23	Sept. 27	70·05	April 21	69·13	Oct. 9
1884	77·15	May 12	70·65	" 16	73·63	May 13	68·80	Nov. 19
1885	78·73	" 1	80·65	Oct. 13	74·47	April 30	68·88	Oct. 13
1886	78·65	April 26	70·73	Aug. 31	74·13	" 24	68·72	Nov. 16
1887	79·23	May 13	69·23	Oct. 10	74·30	May 13	67·80	" 1
1888	78·48	" 21	70·32	" 22	72·80	" 18	67·62	Oct. 23
1889	76·57	June 11	70·23	Nov. 9	71·88	June 11	67·47	Nov. 16
1890	77·65	" 3	70·32	Dec. 7	73·38	" 3	68·55	Oct. 31
1891	77·57	April 30	70·32	Nov. 11	72·97	April 30	66·97	Nov. 10
1892	74·73	" 8	70·48	Oct. 27	71·55	" 7	67·62	Oct. 27
1893	79·15	May 23	70·47	Sept. 27	73·97	May 22	67·80	Nov. 13
1894	77·40	" 3	70·07	" 10	72·05	" 1	67·55	Sept. 5
1895	76·48	" 13	69·98	Oct. 23	70·88	" 13	66·05	Nov. 5
1896	78·57	April 22	70·40	Sept. 10	72·80	April 21	66·80	Oct. 19
1897	77·82	May 5	69·98	Oct. 14	72·30	May 4	66·80	" 21
1898	75·82	Mar. 20	70·90	Sept. 15	72·55	Mar. 19	67·47	" 3
1899	79·23	May 7	70·23	" 16	73·38	May 6	67·13	Sept. 22
1900	76·63	April 26	70·97	Sept. 13	71·97	April 27	67·80	Nov. 1
1901	77·30	" 26	69·30	" 29	72·88	" 10	66·88	" 28
1902	76·13	" 2	70·47	" 7	72·05	Mar. 19	67·97	Sept. 27
1903	76·05	Mar. 25	70·80	Nov. 23	72·55	" 25	67·55	Nov. 24
1904	78·30	May 10	70·63	Sep. 23	73·38	May 13	68·47	" 26
1905	75·23	" 19	70·15	Oct. 11	71·13	April 1	68·05	" 22
1906	75·48	June 10	69·32	Sept. 29	71·22	June 10	67·47	Sept. 24
1907	76·32	May 25	70·65	" 8	72·62	April 1	68·47	Aug. 29
1908	79·23	" 15	....	....	74·55	May 14	....	....

GRENVILLE.

Year.	Upper Lock. Highest.	Date.	Upper Lock. Lowest.	Date.	Lower Lock. Highest.	Date.	Lower Lock. Lowest.	Date.
1870	140·63	April 25	126·55	Oct. 13	96·05	April 30	81·55	Oct. 18
1871	140·22	May 10	126·30	Sept. 26	93·80	May 9	81·59	Sept. 26
1872	138·13	" 25	128·22	Aug. 29	93·05	" 17	82·63	Aug. 31
1873	141·30	June 1	128·88	Dec. 6	95·55	" —30	82·72	Sept. 17
1874	139·47	" 3	127·30	Sept. 29	93·30	" 28	81·63	Oct. 27
1875	140·97	May 19	128·38	Oct. 2	96·30	Mar. 4	82·63	" 2
1876	145·22	" 16	127·13	Sept. 29	99·38	May 16	81·88	Sept. 25
1877	135·10	April 30	127·22	" 29	95·30	Jan. 18	81·88	" 26
1878	134·85	May 12	127·68	" 13	88·47	May 11	82·38	" 10
1879	141·68	" 21	127·52	Nov. 13	95·80	" 21	81·80	Nov. 8
1880	140·43	" 19	128·35	Sept. 25	95·05	" 18	82·63	Sept. 26
1881	138·10	" 19	126·18	" 27	96·80	Feb. 27	81·05	" 27
1882	138·18	June 2	129·68	Nov. 1	95·13	May 31	86·13	Oct. 22
1883	136·68	" 1	129·43	Sept. 24	96·80	Mar. 1	84·80	Sept. 28
1884	138·52	May 15	128·10	" 24	94·97	June 1	85·72	" 19
1885	139·10	April 29	128·10	Oct. 14	99·30	April 29	85·63	Oct. 13
1886	140·52	" 25	128·77	Sept. 16	98·80	" 26	86·05	Sept. 15
1887	141·35	May 11	126·18	" 30	99·55	May 12	84·05	" 29
1888	140·52	" 19	127·60	Oct. 12	98·63	" 21	85·13	Oct. 24
1889	137·68	June 8	127·85	Nov. 6	95·30	June 10	85·30	Nov. 1
1890	139·02	June 2	129·85	Sept. 30	97·05	June 4	86·80	Sept. 30
1891	138·85	April 28	127·93	Nov. 14	97·05	May 4	85·72	Oct. 9
1892	134·85	" 8	128·10	Sept. 16	92·30	April 9	85·97	Sept. 15
1893	141·35	May 21	128·35	" 19	99·80	May 21	86·30	" 26
1894	139·02	" 1	127·52	" 9	97·22	" 1	85·05	" 13
1895	137·85	" 11	127·52	Oct. 30	95·80	" 11	85·05	Oct. 25
1896	139·60	April 23	128·35	Sept. 1	97·63	April 23	85·47	Sept. 17
1897	139·68	May 4	127·68	Oct. 16	97·30	May 3	84·55	Oct. 11

GRENVILLE—*Concluded.*

Year.	Upper Lock. Highest.	Date.	Upper Lock. Lowest.	Date.	Lower Lock. Highest.	Date.	Lower Lock. Lowest.	Date.
1898	136·02	Mar. 20	129·10	Sept. 24	95·38	Mar. 16	86·05	Sept. 21
1899	141·60	May 7	127·60	" 18	99·88	May 8	86·22	Nov. 27
1900	137·60	April 26	129·35	" 10	95·38	April 27	86·30	Sept. 14
1901	138·35	" 25	126·35	" 29	96·55	" 25	83·80	" 16
1902	136·35	" 2	128·52	" 14	94·13	May 6	85·47	" 12
1903	136·18	Mar. 25	128·85	Nov. 30	94·30	Mar. 25	85·72	" 13
1904	140·35	May 11	128·77	Sept. 20	98·47	May 11	86·13	" 14
1905	135·85	" 23	127·68	" 17	99·63	Mar. 16	84·97	Oct. 9
1906	136·02	" 19	126·35	" 29	93·38	May 20	83·88	Sept. 24
1907	137·18	" 26	128·22	" 8	95·38	April 2	85·38	" 9
1908	141·18	" 17	....	....	99·05	May 14	....	....

CARILLON.

Year.	Upper Lock. Highest.	Date.	Upper Lock. Lowest.	Date.	Lower Lock. Highest.	Date.	Lower Lock. Lowest.	Date.
1870	92·45	April 26	78·20	Oct. 12	80·70	April 26	68·28	Oct. 15
1871	90·70	May 7	78·28	Sept. 28	79·20	May 9	69·12	Sept. 30
1872	89·70	" 17	79·62	Aug. 29	78·20	" 17	70·45	" 1
1873	92·20	" 29	79·45	Sept. 11	80·03	" 29	70·20	" 17
1874	90·20	" 24	78·20	Nov. 30	78·62	" 25	69·53	" 31
1875	91·95	" 19	79·62	Oct. 1	80·03	" 19	70·45	Oct. 2
1896	95·95	" 16	78·62	Sept. 18	83·28	" 18	69·62	Sept. 30
1877	85·45	April 28	78·53	" 25	74·70	April 30	69·62	" 22
1878	85·87	May 22	79·12	" 14	74·62	May 12	70·03	" 18
1879	92·20	" 20	78·62	Nov. 4	80·12	" 21	69·78	Nov. 1
1880	92·45	" 18	79·20	Sept. 25	79·53	" 18	70·20	Sept. 25
1881	90·95	" 19	....	....	77·37	" 21	....	....
1882	94·20	" 30	85·58	Oct. 25	77·53	" 30	70·78	Dec. 31
1883	91·33	June 2	84·00	Sept. 23	76·53	June 2	70·87	Sept. 11
1884	95·25	May 11	85·67	" 17	77·91	May 17	70·20	" 24
1885	95·58	April 29	85·42	Oct. 13	81·03	April 26	70·53	Oct. 10
1886	95·75	" 25	86·00	Sept. 21	79·78	" 25	70·78	Sept. 19
1887	96·25	May 10	84·25	Oct. 1	80·53	May 13	69·03	Oct. 23
1888	95·67	" 21	85·00	Sept. 23	79·70	" 20	69·53	" 31
1889	93·25	June 8	85·33	Nov. 2	77·37	June 9	69·37	Nov. 13
1890	94·58	" 2	85·59	Dec. 2	78·70	" 3	....	....
1891	94·58	April 27	85·75	Nov. 9	78·53	May 1	70·28	Nov. 10
1892	90·25	" 8	86·00	Sept. 12	76·03	April 8	70·37	" 5
1893	97·25	May 21	86·42	" 20	80·45	May 21	69·87	Oct. 3
1894	95·00	" 4	85·00	" 15	78·45	" 6	69·95	Sept. 10
1895	94·00	" 11	85·00	Oct. 21	77·37	" 12	69·87	Oct. 26
1896	95·50	April 24	85·33	Sept. 26	79·12	April 24	70·37	Sept. 24
1897	95·25	May 4	85·25	Oct. 11	79·12	May 4	69·75	Oct. 5
1898	90·92	April 29	86·00	Aug. 27	77·20	Mar. 20	70·87	Sept. 1
1899	97·67	May 8	85·25	Sept. 16	79·53	May 3	70·03	" 14
1900	93·50	April 30	86·00	" 9	77·53	April 28	70·87	" 16
1901	94·00	" 26	84·42	" 28	78·45	" 25	69·28	Oct. 5
1902	92·00	" 2	85·33	" 8	76·62	Mar. 31	70·53	Sept. 5
1903	91·92	Mar. 25	85·58	Nov. 29	77·78	" 25	70·53	Nov. 16
1904	95·67	May 11	85·50	Sept. 19	79·53	May 10	71·45	Nov. 26
1905	91·50	" 23	85·00	" 12	75·78	April 7	70·12	Oct. 14
1906	91·58	June 9	83·75	" 29	75·95	May 18	69·28	Sept. 20
1907	92·50	May 25	85·17	" 2	77·12	" 24	70·42	" 10
1908	96·08	" 14	....	....	....	....	....	....

RIDEAU LOCKS.

Year.	Highest.		Lowest.	
		Date.		Date.
1844	144·22	April 22	130·05	October 1.
1845	148·47	May 8	129·72	September 8.
1846	140·30	May 8	126·97	September 22.
1850	143·30	May 15	129·47	September 1.
1851	142·97	May 15	129·72	October 1.
1852	145·22	May 15	130·22	September 15.
1853	140·47	June 1	129·64	September 1.
1854	142·22	May 15	129·05	September 15.
1855	144·14	May 15	129·89	April 1.
1856	137·97	May 1	129·30	April 1.
1857	144·22	June 1	131·89	November 1.
1858	140·47	June 1	130·97	December 22.
1859	142·72	May 22	129·64	February 22.
1860	142·64	May 22	129·64	September 22.
1861	147·30	May 15	130·39	September 22.
1862	143·47	May 8	128·89	September 1.
1863	140·30	May 1	128·39	September 15.
1864	147·39	May 15	127·97	August 15.
1865	141·05	May 1	128·55	October 22.
1866	142·55	May 1	129·05	April 1.
1867	144·80	June 1	129·47	November 22.
1868	139·72		127·97	September 1.
1869	147·22		128·80	
1870	144·22		127·64	
1871	144·72		127·47	
1872	143·89		128·39	
1873	146·89		129·30	
1874	144·55		128·22	
1875	146·05	May 22	129·47	October 2.
1876	151·97	May 16	128·05	September 28.
1877	137·47	May 1	128·14	September 29.
1878	137·55	October 31	128·80	September 14.
1879	147·30	May 7	128·39	November 12.
1880	146·39	May 18	129·31	October 1.
1881	142·72	May 21	127·01	October 1.
1882	142·97	June 2	131·14	October 28.
1883	141·30	July 5	130·89	October 11.
1884	143·30	May 30	129·39	September 21.
1885	143·97	May 23	129·80	October 11.
1886	146·64	May 1	130·14	September 19.
1887	146·72	May 12	127·14	October 24.
1888	146·64	May 21	129·05	October 15.
1889	142·80	June 8	128·97	November 6.
1890	145·14	June 1	130·22	November 28.
1891	144·30	May 8	128·47	October 8.
1892	137·72	April 7	129·55	September 19.
1893	148·47	May 23	129·97	September 21.
1894	144·47	May 1	128·97	September 12.
1895	143·05	May 11	128·55	November 5.
1896	147·80	April 24	128·97	September 19.
1897	145·22	May 2	129·30	October 20.
1898	139·22	April 26	130·55	September 6.
1899	147·97	May 8	129·39	September 16.
1900	142·22	April 28	131·14	September 15.
1901	143·64	April 27	127·80	September 30.
1902	140·64	May 6	130·05	September 13.
1903	140·05	May 19	130·55	September 16.
1904	146·05	June 12	130·39	September 24.
1905	140·13	May 24	129·30	October 13.
1906	140·39	May 19	127·70	September 28.
1907	142·30	May 25	130·14	September 8.
1908	147·47	May 18	127·22	October 19.

DESCHENES RAPIDS.

Year.	Head.				Foot.			
	Highest.		Lowest.		Highest.		Lowest.	
		Date.		Date.		Date.		Date.
1876	198·92	....	....	....	....	....	....	....
1901	....	....	189·64	Oct. 14	185·00	July 3	180·00	Sept. 12
1902	195·14	May 14	190·65	Sept. 13	185·00	May 14	181·07	" 25
1903	194·72	" 17	190·89	Nov. 30	184·83	" 16	181·26	Nov. 30
1904	197·33	June 13	190·89	Sept. 1	187·33	June 14	181·00	Sept. 1
1905	194·47	May 22	190·67	Oct. 11	184·48	May 23	180·68	Oct. 10
1906	195·32	" 18	189·56	Sept. 29	185·23	" 19	179·87	" 10
1908	....	....	189.25	Nov. 23	....	....	....	....

EAST TEMPLETON.

Year.	Highest.		Lowest.	
1905	137·76	May 22	128·06	September 9.
1906	139·16	May 19	128·01	September 19.

BRONSON'S POINT.

1901	....	....	128·27	September 28.
1902	140·72	May 15	130·57	September 12.
1903	139·57	May 15	130·47	September 12.
1904	....	....	132·52	November 28.
1905	140·47	May 25	129·87	September 14.
1906	140·82	May 19	128·23	September 28.

BOOTH'S HEAD RACE.

1905	171·87	May 22	167·47	October 13.
1906	172·97	May 19	164·26	October 10.

SKEAD'S MILLS.

1905	184·18	May 22	180·67	September 7.
1906	185·50	May 23	179·70	October 15.

FITZROY HARBOUR.

1905	194·93	May 22	190·73	October 12.
1906	196·03	May 17	189·93	September 1.

ARNPRIOR.

Year.	Highest.		Lowest.	
1876	251·54			
1905	244·00	May 22	239·59	October 10.
1906	244·92	May 17	238·50	September 25.

BRYSON.

1876	354·28			
1905	346·64	May 20	341·54	November 30.
1906	347·64	May 16	341·29	September 30.

GOWER POINT.

1876	356·13			
1905	350·66	May 20	343·51	October 9.

LAKE COULONGE.

1876	359·05			
1906	353·10	May 17	342·50	October 10.

CULBUTE CHUTE—Chapeau Bridge.

1876	356·06			
1906	354·00		343·00	

PEMBROKE.

1876	375·00			
1905	368·68	May 20	365·28	October 21.
1906	369·83	May 16	364·68	October 5.

AT THE MOUTH OF DU MOINE.

1876	411·42			
1904	403·73		392·25	1905. December 2.
1905	400·84	May 20	391·04	October 10.
1906	404·24	May 14	389·10	October 19.

ROCHER CAPITAINE.

1905	448·30	May 20	441·20	October 17.

KLOCK.

1904	495·34			
1905	486·00	May 20	476·90	October 17.
1906	489·90	May 13	475·75	October 21.

DISCHARGE CURVE AT BESSERER'S GROVE.

From the discharge curve, showing the quantity of water flowing at the different heights of the gauge, together with the records of the Rideau locks, the discharge of the river at Besserers since 1844 was plotted as shown on Plate No. 30. All available information with reference to the temperature and the rain-fall and snow-fall which had been observed for four or five stations above Ottawa were averaged and the results plotted, as shown on the same plate. The snow-fall and the rain-fall are separated. In plotting the snow-fall, it was estimated that one inch of snow equalled 1/10-inch of rain. Some few experiments have been made lately and it would seem from these that this is not an accurate estimate. It depends upon the character of the snow-fall. In general, the amount of moisture in a snow-fall appears greater than the allowance of 10 per cent of the corresponding rain-fall. The results of these experiments are too few to be conclusive, but are given here as a matter of information.

Snow tests at Britannia, Ontario.

Date.	Duration of Snowfall.	Depth in inches.	Area in square inches.	Resultant Water in cubic inches.	Precipitation. in inches.	Maximum Temperature.	Direction of Wind.	Velocity of Wind.	Per cent.	Remarks.
1906.	Hours.					Fahrenheit		Miles per hour.		
Nov. 26–27	27	3·875	144	106·10	·736	28°	N.E.	1.	19·0	
Dec. 3	....	2·500	100	19·15	·192	6°	N.W.	6·	07·6	Very light snow.
" 3	....	2·09	100	21·35	·214	6°	N.W.	6·	10·2	The same snowfall measured 24 hours later
" 6	15	3·00	100	62·70	·627	3°	N.E.	20·	20·9	
" 10	12	1·75	200	38·40	·192	14°	N.W.	6·	11·0	Measured 24 hours after snowfall.
" 14–15	10	1·00	200	114·00	·570	30°	N.E.	20·	57·0	Rain had fallen for about 1 hour before this snowfall was measured, forming a hard crust.
" 20–21	33	4·40	200	....	....	23°	N.	6·	....	
" 26	Night	1·00	....	....	....	22°	....	....	....	
" 27	15	4·87	200	114·74	·574	33°	W.	10·	11·8	Thin crust formed on top of snow.
1907.										
Jan. 10	15·5	2·00	200	40·00	·200	26°	N.W.	5·	10·0	Measured 12 hours after snow had fallen.
" 12	11	2·30	200	49·70	·248	16°	E.	12·	10·8	" " " "
" 14	6	1·40	400	73·20	·183	20°	E.	5·	13·1	Thin crust on top of snow.
" 18	8·5	1·90	400	45·80	·114	8°	E.	4·	06·0	
" 19	10	0·90	400	235·50	·588	33°	W.	8·	65·3	Rain had fallen for about 3 hours before measuring.
" 20	....	{0·60	....	....	....	44°	N.W.	40·	....	Snow flurries all day.
" 22	....	0·10	200	17·30	·086	—4°	N.	8·	12·3	Measured 20th and 22nd together. Hard light snow all day.
" 31	7	2·30	400	64·90	·162	10°	N.W.	5·	07·0	
Feb. 1	4	0·40	264	24·20	·092	38°	E.	6·	25·8	
" 6	6	1·00	240	32·40	·134	4°	N.E.	7·	13·4	
" 10	....	2·19	....	....	·219	32°	W.	10·	10·0	
" 13–14–15	....	3·20	400	119·70	·299	24°	....	Quiet......	09·3	
" 19, 9 a.m.	2·5	0·30	432	14·15	·033	9°	E.	12·	11·0	
" 19, 10.30 a.m.	9·0	3·05	400	134·50	·336	....	S.E.	6·	11·0	
" 21	7+	2·00	400	50·42	·121	10°	N.W.	20·	06·0	
" 24	Night	{2·90	....	....	....	10°	E.	8·	....	
" 27	"	0·50	400	113·60	·284	— 6°	N.W.	5·	08·4	Measured 24th and 27th together.
Mar. 2	9	1·20	400	181·20	·453	34°	S.E.	5·	37·8	Rain, sleet and snow all day.
" 4–5	Nights	1·40	....	....	....	....	....	....	....	
" 14	7	1·50	400	87·70	·219	28°	S.	8·	14·6	
" 19	....	3·00	....	....	·350+	34°	E.	10·	11·6	Could not measure this snow and rain fall owing to ice.
" 24	9	0·28	....	....	·400+	36°	E.	6·	14·0	" " " "
April 8	15	3·00	....	....	·450	32°	E.	10·	15·0	
" 9	Night	0·80	400	29·40	·074	32°	N.E.	15·	09·0	Snow was soft, but very looselv packed.
" 16	"	1·20	....	....	·222	34°	N.E.	5·	18·5	A light rain fell for about 1½ hours before the snow; added with the precipitation.
" 25	8	1·30	....	....	·350	....	N.E.	4·	26·9	Measured in rain guage.

EVAPORATION OF SNOW AT BRITANNIA BAY, ONTARIO.

Tested at a place exposed to very little wind or sun.	Water in cubic inches.	Precipitation in inches.
Top layer—5·4″ thick, cut an oblong 8″ x 20″ = 160·sq. inches, consisting of clear snow, no crust	148·4	0·928″ 17·2 p.c.
2nd layer—3·92″ thick, cut an oblong 10″ x 20″ = 200·sq. inches, consisting of clear snow and one inch of hard crust	222·5	1·112″ 28·4 p.c.
3rd layer—7·62″ thick, cut an oblong 10″ x 20″ = 200·sq. inches, consisting of clear snow and 1¼ inch of hard crust	500·9	2·504″ 32·9 p.c.
4th layer—0·65″ thick, solid ice, estimated to represent one-half inch of rain		0·500″
Total precipitation, minus evaporation, from Nov. 26, 1906, to Jan. 25, 1907		5·044″
Total precipitation, as measured from day to day		5·684″
Evaporation during sixty days		0·640″

FLOODS.

The record high year both for average discharge and extreme rise was 1876.

This appears to have been produced by the floods of the north and south tributaries occuring at the same time. In ordinary years, the high waters of the Mississippi, Madawaska, Bonnechere and Petawawa are over before the flood of the north tributaries begins. No doubt, even in a maximum year, the highest flow of the south tributaries is past before the north tributaries reach their highest point, but the maximum of the two occurs while the south are receding from their maximum and the north ones are approaching theirs. No authentic records exist to prove that this is the case, but lumbermen and others who watch the river closely state this as the reason, and there seems no reasonable doubt of its accuracy.

PROBABILITY OF ITS RECURRENCE.

In December, 1875 and January, 1876, there was a great deal of rain and snow, alternately thawing and freezing, filling the ground storage. This was followed by a very heavy snow-fall in February and March, which was held by cold weather until about the 15th April. On April 15 there was good sleighing in the neighbourhood of Arnprior and the southern part of the water-shed. It then turned warm and the waters of the south and north came in at the same time creating the maximum flood for a short period. Although this extreme flood condition occurred but once in a period of record, the conditions which produce it seem liable to re-occur, and therefore, its return may be expected, and the calculations for river improvements must be based on these extreme conditions.

FLOOD IN 1837 OR 1840 SIMILAR TO THAT OF 1876.

And although the records show but one year with this extreme condition, common reports state that a flood of the same character as that of 1876 occurred about 1840.

The year 1840 is stated to be the time by the inhabitants of the Upper Ottawa, but no levels have been found or any accurate information with respect to it. In the Archives Branch of the Dominion, there is a report written by Mr. Peter Fleming dealing with the flood in the Ottawa river in the vicinity of Montreal in the year 1837.

This very interesting document, after a long description of the methods of calculation, states that the flood in Montreal was 341,000 cubic feet per second. From the methods of computation, it is probable that this might be in error by 10 per cent to 20 per cent. No weather reports exist to guide us whether 1837 was similar to 1876 or not.

Our measurements give as the closest approximation of the flood of 1876, on the same section, as 310,000 cubic feet per second, and, from this deduction, it would seem that the flood of 1837 was of the same character as that of 1876. Not only was the year 1876 the largest flood of record, but the total run-off during the year was also the maximum. For the consideration of the improvements of the river, therefore, the year 1876 was assumed as the basis of calculation for the flood conditions, and although this flood may be expected but once, probably, in a period of forty years, the records of high and low water show that very high water exists about once in five years.

YEARS OF EXTREME LOW WATER.

The years of opposite extreme, namely, low water, are 1846, 1881, 188 7and 1906. Each of these years had some peculiar feature—that of 1906 being noted for its long continuance. These two conditions are those for which the river is to be im-

proved. If the improvements create safe navigation for highest and lowest water, then the safety is guaranteed at any point between them. These two extremes are, therefore considered in detail.

The high and low water of the various years are given in list No. 5.

To illustrate the difference in flow at different seasons, and of different years, Plate No. 25 has been prepared showing the discharge at Besserer's Grove for the years 1846, 1876, 1881, 1887, 1904, 1905 and 1906. Corresponding differences exist at other sections of the river.

In a flood like that of 1876, the character of the river, naturally, changes greatly from that at low water, or even ordinary high water.

The river is generally a series of wide basins with rapids and falls of various lengths connecting them. As the water rises, no serious floods take place below ordinary spring water level. In the lower reaches of the river, however, above this level, the land along the shore being low and flat, much becomes flooded. In the restricted portions, where the banks are high, as the flow increases, currents increase until they are higher than can be navigated with safety.

The preliminary surveys showed the necessity of eliminating the maximum flood conditions in order to limit the maximum currents to four feet per second, which was considered the highest allowable velocity. The storage of the surplus water of the spring has many other advantages in addition to the reduction of high velocities. These advantages are, principally:—

1st.—The reduction of flooded area.

2nd.—Great reduction in the cost of construction. Without a system of control, the various regulating works necessarily would be difficult to build and very expensive. Without them the entire route would have to be excavated 22 feet below extreme low water, which would be almost commercially impossible and the locks constructed for great variation of water levels.

All the other constructions along the route would be affected in the same way. These features are important, but no doubt the principal reason for the system of control is the reduction of velocities at the restricted portions of the river which safe navigation required.

The currents in the restricted portion can be diminished:—

1st.—By dredging and enlarging the section.

2nd.—By raising the water level without storage, and thus enlarging the section.

3rd.—By storing the water in reservoirs and reducing the flood flow.

The improvements of the channel by the first two methods are extremely expensive.

The spring flood of 1905 and 1906 created but few currents serious to navigation. Particular sections at which the currents were high can be improved with reasonable expenditure to pass a flood of the size of these two years. It was decided to determine if sufficient storage existed to control the river in a year of maximum flood so that the extreme flow would not exceed that of the Spring of 1905.

In the following list, the discharge and water level of 1905 at different points is shown with the discharge and fluctuation of the high water of 1876 and the low water of 1906.

N.B.—Since the writing of this report, the very high water of 1908 has demonstrated that the water level can be controlled at a higher level than the Spring of 1904, 1905 and 1906 without any serious damage. The result of this observation shows that less storage would be required than estimated on in this report.

TABLE OF HIGH, ORDINARY AND LOW FLOW OF THE OTTAWA RIVER WITH CORRESPONDING WATER LEVELS.

Locality.	High Water, 1876, Discharge, cu. ft. per second.	Corresponding Water Level, 1876.	Ordinary Service Discharge and Proposed Level, cu. ft. per second.	Corresponding Water Level.	Low Water, 1906, cu. ft. per second.	Corresponding Water Level.	Water Shed in sq. m.
Ste. Anne........	86,550	Upper......	41,399	Upper........	5,820	Upper.......	....
Vaudreuil........	60,400	Ste. Annes...	29,879	Ste. Anne....	2,940	Ste. Anne....	....
Mille Ile River....	35,520	81·07	17,559	75·00	520	69·22	....
Back River.......	127,530	....	64,530	Canal Elv....	12,320	....	....
Total.......	310,000	....	153,400	75·000	21,600	....	56,000
Grenville.........	304,000	U. Grenv'l. 145·22	146,000 117,400	U. Grenv'l. 135·85	21,000	U. Grenv'l. 126·35	54,327
Besserer's........	253,100	R. Locks. 151·97	120,000	R. Locks. 140·00	14,500	R. Locks. 127·70	45,473
Chaudiere........	193,450	H. Desch. R. 198·92	87,000	Chaudiere. 194·24	11,000	H. Desch. R. 189·57	34,623
Chats............	190,000	Foot. 199·6	84,000	Foot. 195·00	11,000	Foot. 189·57	33,975
....	....	Head. 251·24	....	Canal El. H. 245·00	....	....	....
Chenaux..........	159,700	Sand Pt. 251·54	68,700	....	9,760	....	28,,288
R. Fendu.........	91,100	Foot. 295·5	39,800	Head. 348·5	4,965	Head. 342·3	28,224
Calumet..........	65,900	H. of Isd. 355·	28,800	....	4,635	....	....
Total......	157,000	....	68,600	....	9,600	....	....
Paquette.........	125,600	Foot. 359·5	52,400	L. Coul. H. 351·0	6,980	L. Coul. 342·5	25,122
....	....	Head. 368·	....	Canal L. 350·00	....	....	....
Culbute..........	19,400	....	8,100	....	1,620	....	....
Total......	145,000	....	60,500	....	8,600	....	....
Des Joachims.....	123,600	Foot. 374·7	Bel. Black Riv. 52,000	Foot. 370·00	7,860	....	22,148
Rocher Capitaine..	112,800	....	46,000	Foot. 410·00	7,560	H. of Rap. 440·2	20,237
Deux Rivieres.....	112,700	495·3	45,000	Klock. Foot. 470·00	7,500	Klock. 475·7	20,122
....	111,000	H.W., 1904..	....	Head. 500·00	....	....	....

DESCRIPTION OF SURVEY OF RESERVOIRS.

Prior to the commencement of the survey, some of the Upper Lakes in the main Ottawa were investigated by the Public Works Department, and estimates had been made of the cost and quantity of water it was possible to store.

Early in the season of 1906, a party was sent out to investigate other lakes for the same purpose. The first trip of this survey started from Mattawa by way of Kippewa, Trout lake to Grand Lake Victoria. From there up the main Ottawa investigating lakes along the route to the Kakabonga lake at the head of the Gens de Terre river, and from there via the Gatineau to Ottawa, some lakes being surveyed on the way.

The second trip was made up the other branch of the Kippewa river into the Du Moine lake at the head of the Du Moine river and from there across to the head of the Coulonge river and across to the Gatineau and down the Desert river. (See Appendix K.)

PLATE SHOWING LAKES SURVEYED.

The lakes surveyed and reported on previous to this survey are shown on Plate No. 3, and marked by a maltese cross. Those surveyed during the last season are

shown by a red circle. A list of these lakes is given below, with their approximate area, and the raised elevation above low water level which the surrounding country will permit for storage purposes.

Lakes.	Area. Sq. miles.	Possible Height of Dam above Low Water Level, in Feet.	Area raised 1 ft. Sq. miles.
Upper Ottawa—			
Beauchene	17	9	150
Timiskaming	115	8	920
Quinze	100	5	500
Barriere (dam 1)	35	10	350
Barriere (dam 2)	25	10	250
Turn Back	48	10	480
Askikwaj (above height of land)	84	10	840
Grand Lake Victoria	30	13	390
Rabbit	16	10	160
Birch and Awatan	18	10	180
Round	7	6	42
Elbow	10	8	80
Caribou	9	5	45
Chub Caribou	8	11	88
Trout	15	6	90
Big Roger	22	6	132
Big Snake	9	6	54
			4,751
Kippewa—			
Lake Kipawa	110	6	660
Bois Franc	5	10	50
Brennan	5	15	75
Wolf and Brule	11	12	132
Grassy	7	10	70
Osloboning	19	20	380
Big Birch	8	10	80
Meat Bird	11	5	55
Brule and Ross	6	6	36
Garden and Blue	9	6	54
			1,592
Du Moine—			
Big Lake Dumoine	45	10	450
Bark	7	7	49
Seven Mile Lake	5	15	75
Bell and Sucker	5	10	50
Ten Mile Lake	6	15	90
			714
Coulonge—			
Little Victoria	6	12	72
Brule	8	11	88
Giroux	6	10	60
Nishkotea	6	5	30
Big and Dan	7	10	70
Smaller lakes			175
			495
Gatineau—			
Kakabonga	75	15	1,125
Moose	15	12	180
Awashemameka	9	5	45
Island and Pike	15	10	150
Windfall	6	15	90
Tomasine	3	20	60
Rond and Desert	15	15	225
Baskatong	20	10	200
			2,075
Black River—			
St. Patrick	10	7	70
Moose Patrick	5	6	30
McGillivray	3	6	18
			118
Grand total, probably			9,745

Time did not allow of surveys being made of all lakes, but fairly accurate information exists about certain portions of the country, and with the time at the disposal of the survey, it was decided to investigate those lakes which lay further beyond civilization and about which very little reliable information existed. A preliminary statement was made from the reports of agents of the lumbermen and from the lumbermen's improvements, of the storage which exists in better known portions of the water-shed.

But in addition to this, there are about 10,000 square miles of the Upper Ottawa and its tributaries which are unexplored, and about which very little is known except that it is a country similar to that which has been explored and surveyed, that is, covered with forest and numerous lakes. In all portions of the water-shed where lumbering operations have been carried on, the lumbermen have operated dams for the purpose of driving logs into the main rivers. Usually, these dams are closed in the fall, and the water accumulated in order to be sure that the lakes will fill in the spring in case the spring is a low one. Generally, these dams are constructed so as to hold the water just above high water mark.

From the preliminary investigation made in the field, and from information gathered from all available sources, the following table of storage possibilities has been prepared.

TABLE OF STORAGE POSSIBILITIES.

River.	Drainage Area in square miles.	Maximum Flow in C.F.S.	1 Storage examined in 13,300 sq. miles of Drainage Area	2 Storage from Lumbermens' Reports of 22,700 sq. miles of Drainage Area.	3 Unexplored 9,000 square miles of Drainage Area estimated on basis of Proportion Explored.	Assumed Total Storage.	Maximum flow with Storage.
Upper Ottawa, above Kippewa....	15,000	....	4,751 sq. m. by 1 foot	2,214 sq. miles by 1 foot. ..	3,168 sq. miles by 1 ft., or 32 p.c. of drainage.		
Kippewa........................	2,133	....	1,592 "	54 " " ..			
Mattawa........................	880	....	568 "				
Du Moine	1,517	5,800	714 "	80 " " ..			
		1905.					
Petawawa.......................	1,586	5,000	....	560 " " ..			
Black..........................	950	6,600	....	150 " " ..	130 sq. miles by 1 foot, or 44 p.c. of area (not expected to be so much.)		
		1906.					
Coulonge.......................	1,820	12,500	495 sq. m. by 1 foot	254 " " ..			
Bonnechêre	910	4,000	....	400 " " ..			
Madawaska......................	3,210	....	....	..1,100 " " ..			
Mississippi....................	1,400	7,750	....	480 " " ..			
Gatineau.......................	9,130	49,000	2,075 sq.m. by 1 foot	864 " " ..	2,700 sq. miles by 1 foot, or 49 p.c. of area.		
Totals.........................	....	....	10,195 sq.m. by 1 foot	6,156 sq. miles by 1 foot.	5,898 sq. miles (22,057 by 1 foot, assume 20,000 by 1 foot)		

EFFECT OF STORAGE SURVEYED ABOVE BESSERER'S GROVE.

Above Besserer's Grove there is a drainage area of 45,473 square miles. This territory has been divided into the various tributary drainage areas under three headings, in the preceding table:—

1.—Storage examined (included in certain drainage area).
2.—Storage estimated from lumbermen's reports (and maps of drainage area).
3.—Storage estimated in unexplored country.

No doubt, in the portion examined (namely, 13,300 sq. miles of drainage area out of a total of 45,000 sq. miles) the largest lakes exist, but it is well known that of the country, estimated in column No. 2, with 22,700 sq. miles of drainage area, which includes the south tributaries and much of the north tributaries, many lakes with large storage occur. From the maps and reports of the lumbermen, description and estimates covering a proportion of this territory were made which are shown in column No. 2. Many lakes occur in this district, which are not included through lack of more definite information.

Column No. 3.—The unexplored country includes the head waters of the Black, the Montreal, the Blanche (running into Lake Timiskaming) the Ottawa, northeast of Expanse and the upper waters of the Ottawa and the main Gatineau rivers. From the reports of surveyors and engineers of the various railroads, and lumbermen, it is known that numerous very large lakes exist in this territory, but for safety only 50 per cent in proportion of that found in the surveyed district was allowed for this territory. Doubtless, if smaller lakes were included, the entire storage could be increased by 25 per cent, but by so doing the cost of operation and construction would be very largely increased.

From the foregoing figures, it seems proper to state that at least 20,000 sq. miles by one foot exists above the section at Besserer's Grove.

For uniformity, storage has been estimated in square miles by one foot. The total cost includes some damages for land flooding. The value of the land flooded, generally would be insignificant. In some cases, damage might be done to standing timber, but this could be removed prior to construction, and most of it of any value on account of its accessibility has been already removed.

COST OF RESERVOIRS.

The dams are proposed to be built of timber similar to those now operated by the lumber interests, but more efficiently equipped. The total cost of the reservoir system is estimated at $2,000,000. More detailed study might vary this but not to any great extent.

The average height of the reservoirs is about 10 feet. This height is generally controlled by the outlet where any additional height would only be given by great lengthening of the dam section and by increasing the cost. But in other cases, any further raising of the lake is prohibited from the fact that by so doing the water would find other outlets draining, sometimes in the same river and sometimes into other tributaries. This is quite noticeable at the height of land where already the lumbermen, to avoid long driving of the logs, have taken advantage of it and have thrown certain parts of one water-shed into another. In quite a few lakes the height of the reservoir is limited by the drainage area tributary to it not giving it sufficient water to fill it to the maximum height of possible construction.

NON-INTERFERENCE WITH LUMBERING OPERATIONS.

The construction of these reservoirs is expected to assist the lumber interests operating in the district. The lumbermen now operate certain reservoirs with which

to drive their logs. The two conditions which the storage is designed to eliminate are, extreme high and extreme low water.

As the occurrence of these create serious damage to the lumber interests, their elimination would be beneficial.

The following calculation shows the effect on the flow of 1876 at Besserer's of 20,000 square miles by one foot of storage, which is the estimated storage of the water-shed as previously shown.

The calculated daily discharges for that season are as given in the following tables:—

THE FOLLOWING LIST GIVES DISCHARGE AT BESSERER'S GROVE, 1876, IN CUBIC FEET PER SECOND, FOR THE MONTHS OF APRIL TO AUGUST INCLUSIVE, AND CORRESPONDING GAUGE HEIGHTS.

Day.	Elevation.	April.	Elevation.	May.	Elevation.	June.	Elevation.	July.	Elevation.	August.
1	132·80	48,936	142·66	147,776	148·22	210,100	140·90	127,660	133·47	53,800
2	132·81	49,632	143·01	151,664	147·93	206,900	140·64	121,636	133·33	52,750
3	132·83	49,128	143·35	155,552	147·64	203,700	140·37	121,635	133·18	51,700
4	132·84	49,224	143·70	159,440	147·20	198,529	140·11	118,622	133·04	50,650
5	132·85	49,320	144·04	163,328	146·76	193,560	139·84	115,609	132·89	49,600
6	132·86	49,416	144·39	167,200	146·32	188,591	139·58	112,596	132·76	48,626
7	132·88	49,516	145·23	176,680	145·88	183,622	139·31	109,583	132·63	47,855
8	132·89	49,613	146·08	186,160	145·44	178,853	139·05	106,570	132·50	47,084
9	133·38	53,357	146·92	195,640	144·99	173,884	138·91	104,950	132·36	46,313
10	133·86	57,101	147·77	205,120	144·55	168,915	138·68	103,320	132·23	45,542
11	134·35	60,845	148·61	214,600	144·48	168,107	138·62	101,690	132·10	44,771
12	134·84	64,589	149·46	224,080	144·41	167,300	138·48	100,070	131·97	44,000
13	135·33	68,333	150·30	233,560	144·34	166,493	138·34	98,430	131·85	43,010
14	135·81	72,077	151·05	242,040	144·27	165,686	138·19	96,800	131·73	42,025
15	136·30	75,820	151·80	250,520	144·19	164,879	138·05	95,170	131·61	41,040
16	136·90	82,524	151·73	249,817	144·12	164,072	137·71	91,636	131·50	40,055
17	137·49	89,228	151·67	249,122	144·05	163,265	137·36	87,990	131·38	39,070
18	138·09	95,932	151·60	248,408	143·93	162,854	137·02	84,244	131·26	38,085
19	138·68	102,636	151·54	247,704	143·81	161,445	136·67	80,598	131·14	37,100
20	139·28	109,340	151·47	247,000	143·69	160,036	136·33	76,942	131·00	36,074
21	139·87	116,044	151·26	243,000	143·58	158,627	135·98	73,296	130·85	35,060
22	140·47	122,750	151·04	239,000	143·46	156,218	135·64	69,650	130·71	34,046
23	140·68	125,214	150·83	235,000	143·34	154,809	135·40	67,894	130·57	33,032
24	140·90	127,678	150·62	231,000	143·22	153,400	135·16	66,130	130·43	32,028
25	141·11	130,142	150·40	227,000	142·88	149,580	134·92	64,366	130·28	31,014
26	141·33	132,606	150·19	223,000	142·53	145,763	134·69	62,602	130·14	30,000
27	141·54	135,070	149·97	219,000	142·19	141,946	134·45	60,838	130·08	29,692
28	141·76	137,534	149·62	217,200	141·84	138,029	134·21	59,064	130·03	29,287
29	141·97	140,000	149·27	215,440	141·50	134,312	133·97	57,300	129·97	28,882
30	142·32	143,888	148·92	213,660	141·15	130,495	133·80	55,400	129·92	28,377
31	....	....	148·57	211,880	....	....	133·64	54,000	129·86	27,972
Total	....	2,637,383	....	6,590,591	....	5,013,970	....	2,746,291	....	1,238,541
Average	....	87,910	....	212,599	....	167,132	....	88,590	....	39,953

Discharge above elevation 140 during April = 138,285 cubic feet per second for one day.
" " " May = 2,951,169 " " "
" " " June = 1,491,960 " " "
" " " July = 19,952 " " "

Total discharge above elevation 140...... = 4,601,366 " " "

Discharge below elevation 140 until water drops to elevation 130—

July	=	2,256,838	cubic feet per second for one day.
Aug.	=	1,153,310	" " "
Total................	=	3,410,148	

4,601,366 cubic feet per second for one day = 397,558,022,400 = 14,260 square miles raised by one foot.
3,410,148 cubic feet per second for one day = 294,636,787,200 = 10,569 square miles raised by one foot.
50 per cent of this = 5,284 square miles by one foot.
Total required, 14,260 + 5,284 = 19,544 square miles.

It will be noticed from the figures in the table that the river begins to rise about the 1st April, and continues to rise until May 15, and then falls gradually, reaching about the same level at the end of July as it was on the 1st of April. If it is desired to restrain the water at elevation 140, or ordinary spring level, which corresponds to a flow of 117,000 cubic feet per second, it is necessary that on April 21, when the water reaches that state, that certain water pouring into the river at Besserers should be restrained from entering the main river, or rather, some days previous to April 21—say April 15—the water, which on the later date reaches Besserer's Grove, is pouring from the storage lakes unimpeded; then, on April 16, a certain portion of the reservoir capacity has to be employed to restrain the water which reaches Besserer's on April 22, and every day thereafter, certain additional storage must be called upon.

In the list, it is seen that the difference between 122,750 and 117,000, or 5,750 cubic feet per second, is the excess which must be stored on April 22 to control the river at elevation 140 at Besserer's—the difference between 125,214 and 117,000, or 8,214 cubic feet per second must be stored on April 23, and so on until July 4, when the flow falls to 117,000 cubic feet per second again.

The total amount to be stored in April is 138,285 cubic feet per second for one day; in May 2,951,169 cubic feet per second for one day; in June 1,491,960 cubic feet per second for one day; and in July 19,952 cubic feet per second for one day—a total of 4,601,366 cubic feet per second for one day. 4,601,366 cubic feet per second for one day, as there are 86,400 seconds in one day, equals 397,558,022,400 cubic feet which equals 14,260 square miles raised by one foot.

On April 22nd, however, or the number of days previous to this that it takes the water to reach Besserer's, the entire water-shed is in a certain condition, the lakes having been raised above low water to a height corresponding to elevation 140, or ordinary spring level.

It was impossible to determine this level, as no gauges are in existence on the majority of the lakes. Our estimate of storage is above low water mark. Therefore, to the above required storage must be added the additional storage required above low water mark.

It is difficult to calculate what this should be, as a basis, presume that elevation 130 at the Rideau locks is low water mark and the stage at which the reservoirs might be considered empty. The total amount of water flowing from July 4, when the water is at elevation 140, to August 28, when the elevation is 130, can be divided into two items.

1. The inflow into the lakes which are to be constructed into reservoirs.

2. The water drawn from the natural storage of these lakes as the water falls in the lakes from ordinary spring level corresponding to elevation 140 to low water mark corresponding to elevation 130.

It is difficult to estimate the proportions of both but the natural storage of the lakes which are to become reservoirs is not probably one-third of the flow from July 4 to August 28, but in estimating 50 per cent a factor of safety is assured.

The total discharge from July 4 to August 28 is 3,410,148 cubic feet per second for one day, or 294,636,787,200 cubic feet, or half of this storage, or 147,318,393,600 cubic feet, or 5,284 square miles by one foot, which represents the additional storage above low water mark to ordinary spring level of the storage lakes.

The entire reservoir capacity required above low water equals 14,260, plus 5,284, or 19,544 square miles by one foot. Although 25 per cent more storage exists, it was considered wiser to use 20,000 square miles by one foot as the basis of computation. As the reservoirs average ten feet in height, this represents a lake area of 2,000 square miles. It is therefore seen that the flood flow of 1876 can be controlled at elevation 140, or ordinary spring level.

Further research may show the advisability of increasing this level.

It has been assumed in the above calculation that the run-off is proportional to the drainage area, and no other hypothesis seems reasonable.

The important feature in connection with the problem is the time factor. It has been pointed out previously that the high water of 1876 appears to have been caused by the combination of the high water of the south and the north tributaries. In ordinary years, the high water of the south tributaries is over before that of the north tributaries occurs, but in the year 1876, and in some other years, the combination of the two took place. Heavy rain-fall over the south tributaries, combined with heavy rain-fall and melting snow from the woods of the north tributaries. It has also been found from the records that the high water of the main Ottawa at Mattawa and of all the north tributaries with the exception of the Du Nord, near Montreal, occurs within a day of each other. Such being the case, the entire drainage area of the north can be considered collectively. If only a few reservoirs were to be constructed, their position would have to be judiciously selected. There is no doubt that the administration and the determination of the time which it requires the waters to come from the various reservoirs, must be considered carefully. But, in estimating the watershed flow from April 15 to July 30, and providing for the storage of all excess water above a certain period, ample protection is given.

As noted above, the effect of storage was considered more minutely for Besserer's Grove section by reason of our more complete records.

By a similar computation from the flows at various sections, and the reservoir capacity above them, the flow at which the various reaches could be controlled was calculated. A larger factor of safety was assumed at other sections, where our data on the flow of 1876 was not so complete.

These controlled flows practically represented the flow of an ordinary low spring as that of 1905, and are shown in List No. 1. If no yearly fluctuations in the river existed, the storage could be regulated so that very little fluctuation in the flow of the river would take place, but as the average flow of a high year is from 50 per cent to 100 per cent greater than that in a low year, regulation works have to be constructed at various points along the river to control the water and prevent fluctuation.

These regulating works are at Montreal, Grenville, Chaudière, Chats, Chenaux, Calumet, Paquette, Des Joachims, Rocher Capitaine and Deux Rivieres.

GRADIENT.

The high water flow will, in some of these reaches create a gradient causing a fluctuation from high to low water at the upper end of the reach. From the sections and present slopes, this is calculated to be three feet at Mattawa; about 6 inches at the foot of Deux Rivieres; one foot at the foot of Rocher Capitaine; one foot at the foot of Des Joachims; two feet at the Cheneaux; two feet at the foot of the Chats; from two to three feet at the foot of the Chaudiere and the same amount at the foot of the Carillon.

By controlling the flood, the entire character of the river is changed, and practically slack water navigation created. With the exception of a few restricted sections, in which the maximum current will not exceed four feet per second, and safe navigation is therefore assured.

It seems justifiable, therefore, to state that the improvement of the river by means of storage is a work of great importance, and one upon which the safe navigation of the canal appears dependent. The information collected to date shows that sufficient storage exists to control the river at ordinary spring level, with the flows shown previously, and from the surveys made and information collected, the cost of the storage reservoirs is not excessive when compared with the benefits derived. Their operation is, however, a question of some moment by reason of their number and inaccessibility, but it is believed that a more extended study will develop a system by which this can be done at a reasonable cost. This would probably require the

construction of telephone lines and some other minor work, but it is not expected that the inaccessibility of this country can continue for any great period.

Aside from the advantages to future navigation to be obtained from them, there are others which in themselves are sufficient to guarantee the construction of many of them, if not the total number. The flood of 1876 is still sufficiently well remembered by those engaged in industries along the river to state that its recurrence is greatly feared. At that time, the river, particularly at Ottawa, was very much less restricted, and the improvements and constructions built since then by the various power-users have now no doubt seriously interfered with the free flow of the river. It is impossible to estimate what the resulting damages might be in case of a recurrence of the flood of the magnitude of that of 1876. It would close down mills and power-houses and destroy dwellings and buildings and the resulting loss would be excessive.

Owing to the recurrence of low water, navigation at present in the different reaches of the river is seriously hampered. Water-power users along the river have also been forced to close down, partially or completely, for considerable periods of time. Navigation and power interests have repeatedly requested the Government to construct a number of storage reservoirs at the head-waters of the Ottawa, and eliminate this extreme low water period.

Very low water in Montreal harbour and the St. Lawrence appears to be coincident with the low water in the Ottawa, and any increase in the low water flow of the Ottawa would have some effect on the St. Lawrence and Montreal harbour. No curve of discharge of the St. Lawrence exists from which the effect of this increase can be accurately calculated.

The question was taken up with the chief engineer for the Harbour Commissioners of Montreal, and he gave his opinion—although lacking data upon which to give a very definite one—that increasing the level of the Ottawa by one foot would have a corresponding effect on Montreal harbour of five inches. This could only be decided if the flows of the river at the various times were known. But, as the low water level at upper Ste. Anne could be increased over two feet, this would increase Montreal harbour and the St. Lawrence one foot. As, during the last summer, when very low water existed in the Ottawa river, vessels had to leave Montreal harbour only partially loaded, it can really be seen how great an improvement this raising of the water level by one foot would make. This feature is worthy of more extensive study and would require gaugings of the flow of the St. Lawrence at different localities.

ALEXANDER McDOUGALL.

WATER POWERS.

Another important question closely connected with the project, is that of water power, which is destined to do so much in the future development of our country.

On the Ottawa river, even in its present condition, the force unused is enormous. Efforts should be made to render this force available and easy of development, and as permanent as possible. As a factor in the growth of a city and its industrial activity, power is of the greatest importance, if it can be produced at a comparatively low cost. In many cases it will provide a basis for new communities. If within close proximity of lines of cheap transportation, then it possesses all the elements of success, and it is bound to attract attention some day for the development of industries.

It has been shown that the scheme of improvement for a 22 foot waterway, on the streams utilized for that purpose,—and the only project admissible,—is by means of locks and dams.

Basins of various lengths are created, concentrating at the foot of each, practically all the fall existing between two levels thus bringing together scattered and uncontrolled force and placing it within possible reach of economical and industrial enterprise.

In connection with the canalized rivers, power will be available only on the French and Ottawa rivers, it being imposible to use any water on the Mattawa section of the waterway for power purposes, as it will all be required for lockages.

What has been said in regard to the importance of regulating the flood waters for navigation purposes, the preservation of forests, &c., applies also to the question of water powers.

The amount of power available is governed by the low flow of the rivers, and on streams which have excessive variations, the value and permanency of water powers is much impaired.

The ideal condition for large industries depending on water power, is to be assured as near as possible of a regular average flow.

Average flow represents the stage of the river assuming it to remain constant from one day to another all the year through. It is practically the actual condition that would exist for the Ottawa valley, should a perfect system of reservoirs be constructed, so that the floods could be held back and distributed during the low water season.

These ideal conditions are impossible to attain in practice for a large river like the Ottawa on account of extreme fluctuations of flow. The ordinary low flow can, however, be much increased by the reservoir system, and in considering water powers this question of increased average low flow is of great importance.

A prominent example in this case, where the increase in the low flow by means of reservoirs, has benefitted industries is that of the Mississippi river already mentioned. At Minneapolis, the possibility of depending on an increased low flow as compared with conditions before the present storage system was commenced at the head of the river, has given a large impetus to water-power development, and apart from those already established, large projects are under consideration.

In the reports, U.S. Chief of Engineers, it is stated that the reservoir system has already directly benefitted the milling interests of Minneapolis to the extent of $500,000 annually, the production of flour by water power amounting to 16,000,000 barrels at less than one cent a barrel, which by steam would cost 5 cents.

In all projects related to the question of water power development, great attention is now paid to the preservation of forest areas at the head of streams, and the following resolution adopted by the Board of Directors of the American Institute of Electrical Engineers, January 10th, 1908 is of great interest.

> 'Whereas, The American Institute of Electrical Engineers recognizes that water powers are of great and rapidly increasing importance to the community at large, and particularly to the Engineering interests of the country, and,
>
> 'Whereas, The value of water powers is determined in great measure by regularity of flow of streams, which regularity is seriously impaired by the removal of forest cover at the headwaters with the resulting diminution in the natural storage capacity of the watersheds, this impairment frequently being permanent because of the impossibility of reforestation, owing to the destruction of essential elements of the soil by fire and its loss by erosion; therefore
>
> 'Be it resolved, That it is the opinion of the American Institute of Electrical Engineers that the attention of the national and state governments should be called to the importance of taking such immediate action as may be necessary to protect the headwaters of important streams from deforestation, and to secure through the introduction of scientific forestry and the elimination of forest fires the perpetuation of a timber supply.'

In our country, fortunately, there is yet time to take measures to protect the forests from the standpoint of timber supply as well as for the protection of water powers, but the question does not permit of much delay.

An understanding between the provinces and the federal government governing the exploitation of forests, by severe and enforced regulations of the annual cut, and the prevention of fires would go a long way towards maintaining the forested areas.

Another matter which will have, some day, to come under discussion and form the subject of an agreement between the provinces of Ontario and Quebec and the federal authorities is the control and disposal of water powers on the Ottawa river and other rivers proposed to be canalized for the deep waterway.

Early in 1906 this was set forth in the following recommendation to the department:—

> 'In relation to the existing water powers along the proposed Georgian Bay Ship canal route, as there is a possibility that the construction of this canal may at some future time be undertaken as a government enterprise, it is very important that the requirements of navigation should be considered in the sale or leases of any water power owned by the provincial or Dominion governments.
>
> The different streams which should receive careful consideration, and which no doubt should come under the rulings of some kind of agreement between the Dominion and the Ontario and Quebec governments are:—the French river, the Pickerel river, the Mattawa and Ottawa rivers, including all the channels of the last-named waterway.
>
> Also all the tributaries to these rivers, where waterfalls are so situated that they might be affected by a permanent rise in the main rivers for navigation purposes.
>
> We are under the impression that there are now several applications before the two provincial governments interested to purchase or lease certain water powers on the above-mentioned rivers.
>
> For instance it is stated that the Quebec rights of Great Calumet falls, the Rocher Capitaine and the Des Joachims falls of the Ottawa river, are under option to sell to certain capitalists, and that the Ontario Power Commission just appointed will consider the great powers on the Ontario side.
>
> These powers, as well as all other powers, will naturally be affected considerably by the canal construction. Rapids and falls will be obliterated in most

cases, by the creation of raised permanent reaches, the powers being thus shifted to the localities where dams will be built, etc.

No doubt if these rapids and falls are owned by private individuals without any reservations, there will be claims to obtain money from the government, even if the same amount of power is offered as a compensation at the nearest locations where dams are constructed.

The question is of the most serious importance if considered in regard to the French and Mattawa rivers. Our information is to the effect that some people are inquiring for power on the Mattawa river at Talon chute. Any power that would be built there, as well as on the French, would utilize the total available flow if the development was of any size at all, and this would render the problem of canal feed at the Summit level much more difficult and involved, as these power developments would necessarily have to be purchased. In this instance, it would be advisable, if it is possible to do so, to have the Ontario government withdraw these powers from sale until it has been decided whether the canal is to be built.

All along the route considerable power will probably be required at different points for canal purposes, such as lighting, power for locks, etc., and we think, it would be wise if the Dominion government were to notify the provincial governments to the effect that in a sale or lease of any of the waterfalls along the route, a stipulation should be put in the agreement setting forth that the government has a prior right to all water required, not only for navigation, but also for lighting, manipulation of lock gates, valves, etc. In most cases of the sale of such water powers, the provincial governments sell also the land alongside of the water power and as in many cases land would be required for locks and other works it might be well to suggest that before any such sale is consummated the provincial authorities submit such agreement to the Dominion government.

In the text of any agreement a rider could also be inserted to the effect, that, should a power be leased, in the event of the construction of the canal and the necessary expropriation of that power, the capital invested only to be considered and not the future or prospective profits.

It is generally claimed, we believe, though we understand this claim is disputed, that all the water powers lying between Ontario and Quebec along the Ottawa river are owned by the Dominion government.

If there is any probability of this being so, we would suggest that the Dominion government should declare their rights as such action would certainly prevent a great deal of trouble in deciding as to the final construction lines of the canal and avoid many troublesome claims. The powers that have been already sold and are still undeveloped must also be considered, and it is necessary to know if the Dominion has any preferential rights as to these in the furtherance of a national canal system for purposes of navigation.

As to the powers already developed, where large interests are involved, no doubt compensation will have to be paid if the owners are even slightly disturbed in the enjoyment of their privileges and rights.

But even in these cases, the government should fully control future improvements, alterations or enlargements of the powers used by the different industries, in order that existing difficulties in designing and constructing a large canal be not increased.

The conditions regarding the lumber industry as now carried out will necessarily be changed if the canal is built, and from these interests as well as from others it is possible that opposition to the canal may be developed. There may also arise claims of exclusive rights granted to individuals, and it would be well to know whether any such exclusive rights exist, and to know also if rights claimed as such could be sustained in impairment of public interest in case the canal is built as a national work.

In any case, we believe that steps should be taken at once, and an agreement reached with the interested provincial authorities, that no privileges or rights be granted, no sales or leases be made, of any of the water powers on the Ottawa river without the consent and approval of the Dominion government; that all privileges applied for or sales or leases proposed to be made on the Mattawa and French rivers be withheld until the Dominion government has made known its decision regarding the construction of the canal.

We therefore respectfully suggest that it would be of the utmost importance that any future application for water powers along the proposed route, or for changes or additions in the development of powers already occupied, should be submitted for report and recommendations to a permanent committee composed, say, of three engineers connected with the Georgian Bay Ship canal investigation, and a departmental law officer as legal adviser.

We believe this would greatly help in having water power industries developed on lines that would not interfere with navigation, should the waterways under consideration ever form part of a large transportation route.

As we are under the impression that lots along the Ottawa river were reserved by the Dominion government many years ago, may we suggest that the departmental law clerk be instructed to look this matter up, and compile a list of such reservations and obtain copies of plans showing the location of lots so reserved.'

It is again earnestly recommended that the above be given early attention.

It may even be said that it will be greatly to the public interest if these water powers are acquired by the Dominion government, and their acquisition seems an absolute necessity if the waterway is ever to become a reality.

Several reasons may be given to support this statement:—

1st. Despite statements to the contrary, the great water powers of this country, now undeveloped and within easy reach, are not numerous.

2nd. The majority of the powers on the Ottawa cannot be developed properly except by the two sides of the river jointly. As this requires the merger of different and often opposing interests, it will be almost impossible to accomplish a proper development by the present control of the two provinces, one on each side of the river, and the present methods of sale.

3rd. Their proper development requires the storage of the surplus water to supplement the low water period, and thus enhance their value. This only can be done by the Dominion, as already projected for some of the large lakes of the Upper Ottawa valley, considering at the same time the requirements of navigation.

4th. The dual control of the provinces, is bound sooner or later to develop litigation between the two sides of the river and ultimately the parties interested will call on the Dominion to come to their assistance, as evidenced at the Chaudiere falls during the past few years.

5th. If controlled by the Dominion government entirely, then a fair return could be obtained from the various water powers, and a much larger and more perfect development would be possible.

For all these various reasons, which could be elaborated to a much greater extent, it is obvious that it would be in the public interest for the Dominion government to acquire these water powers.

It has been stated also that their acquisition and absolute control is a necessity if the proposed waterway is to be built now or in the near future.

The present plans for the waterway almost completely change the actual condition of the river. Many powers are obliterated and others are created, while the value of some is greatly enhanced.

If these powers, which under the requirements of the navigation scheme are to be obliterated, are allowed to be developed by different parties, the damages to pay in case of canal construction will be very large.

For the other powers, conditions will be so changed, that unless designed at first along the lines of the canal project,—and the first cost then would be excessive for initial development—heavy damages will also be claimed if the canal is constructed.

The plans proposed create at least twelve large water powers which consume the entire head of the river from Mattawa to the Lake of Two Mountains, apart from the possible two powers on the Back river should that route be selected for the waterway.

It is estimated that nearly 1,000,000 effective horse-power will thus be made available.

These powers by reason of the canal construction and the storage created at the head-waters form one of the chief features in the building of the canal, and if properly administered, would ultimately, as industries would gradually be established, go a long way towards paying interest on the total cost of construction.

Power will be required also by the administration of the waterway proper, for operating lock gates, valves, and for lighting the route for night navigation.

It may be cheaper for the government to develop this at one power, or a proportion at several powers, and this might be the source of friction or trouble with the lessees from the provincial governments if the powers continue in their control. The large water powers of the Ottawa river in its present condition are the Chaudière, the Chats, the Grand Calumet, Des Joachims and the Rocher Capitaine; the Chaudière being the only one extensively developed. There are numerous other powers of lower capacity, but those mentioned above apart from the Chaudière, are the big undeveloped powers, with heads varying from 25 to 50 feet, which can be conveniently developed at present, but requiring the building of extensive dams and the excavation of long canals for proper development. The low flow of the river available varies from 7,000 to 12,000 cubic feet a second, depending upon their situation in the river.

By the plans for the waterway, the flow with the proposed storage, will be augmented at low water season, the number of available sites for powers increased, and in addition the navigation requires the construction of dams which are in themselves the most expensive part of the power development. But these dams in general are larger than a power company would undertake for development purposes only. Therefore, it is clear that ultimately owing to the work of the federal government, the energy available will be of from 15 to 20 times more valuable than it is at present, and it would seem to be good business for the Dominion to acquire the powers now if they could be reasonably purchased.

Mr. Alexander McDougall, hydraulic engineer, who was commissioned to collect data as to the powers on the streams utilized for the proposed waterway, submits the following report and tabulated statement of power possibilities.

Name of Power Site.	Distance from Montreal.	Drainage Area in Sq. Miles.	Proposed Regulated Elevation above Sea Level.		Fall.		Maximum Discharge in Cubic Feet per Sec., 1905.	Maximum Discharge in Cubic Feet per Sec., 1876.
			Head.	Foot.	Low Water.	High Water.		
Lachine	......	......	......	......	......	......	......	......
Ste. Anne	......	......	......	......	......	......	......	......
Riviere des Prairies	......	......	40	16	......	......	64500	128000
Recollet	......	......	75	40	......	......	......	......
Pointe Fortune	49·50	54507	115	75	......	......	......	304900
Hawkesbury	60·00	54327	140	115	......	......	146000	304000
Chaudiere	126·80	34623	195	175	......	......	87000	193000
Chats	154·75	33975	245	195	49·2	48·9	84000	190000
Chenaux	174·30	28288	280	245	0·5	......	68700	159700
Grand Calumet Falls	......	......	350	280	57·0	56·0	28800	65900
Rocher Fendu No. 1	187·40	28224	315	280	53·0	47·0	39800	91100
Rocher Fendu No. 2	190·25	......	350	315	35·0	35·0	39800	91100
Paquette and Allumette	209·50	25122	370	350	9·0	......	52400	125600
Culbute Chute	......	......	370	350	20·0	15·8	8100	19400
Des Joachims	265·60	22148	410	370	27·0	30·0	52000	123600
Rocher Capitaine	283·80	20237	470	410	42·5	42·0	46000	112800
Deux Rivieres	296·60	20122	500	470	......	......	45600	112700
Mattawa	318·50	880	510	500	......	......	......	......
Plain Chant Chute	321·00	825	540	510	18·0	18·6	2500	......
Les Epines Rapids	327·00	807	557	540	11·0	......	2975	......
Lower Paresseux	331·80	344	617	557	......	......	......	......
Upper Paresseux	333·25	344	677	617	41·0	......	1505	......
North Bay	357·80	......	677	648	......	......	......	......
French River	......	......	......	......	......	......	......	......
Big Chaudiere	389·50	4077	648	624	24·3	......	4500	6870
Five Mile Rapids	403·10	4530	624	600	19.0	......	......	......
Dalles	440·10	6900	600	578	4.5	......	4000	......
Totals	......	......	......	......	......	......	......	......
Average	......	......	......	......	......	......	......	......

Low Water Development. — Under present Conditions.							Regulated Low Water Development. — Ganalized River and Storage.						
		Horse Power.							Horse Power.				
Discharge in Cub. ft. per Sec.	Effective Head.	Theoretical.	Turbine Shaft.	Electrical Generators.	Total Capital Cost.	Capital Cost per Electrical Horse Power.	Discharge in Cub. ft per Sec.	Effective Head.	Theoretical.	Turbine Shaft.	Electrical Generators.	Total Capital Cost.	Capital Cost per Electrical Horse Power.
						½						$	$
......	......	......	......	......	......	......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......	......
8000	......	......	......	......	......	......	18500	22	46250	37000	35150	1983163	56·42
8000	......	......	......	......	......	......	8000	35	31770	25400	23400	1401000	59·87
17400	13·5	26650	21300	19300	1548000	80·20	43950	40	199455	160000	148000	6038000	40·80
17300	12·0	23550	18840	17900	1637000	91·45	43800	19	94416	75500	71800	4578000	63·76
11000	......	......	......	......	......	......	28000	20	63530	50830	45000	2549000	56·64
10700	48·0	58270	46500	43300	2764000	63·83	27400	48·5	150770	120600	113500	4875000	42·95
9760	......	......	......	......	......	......	23000	35	91330	73060	68300	2841000	41·60
4635	56·0	29450	23600	20100	1351000	67·21	9700	69·5	76485	61190	56000	2263000	40·41
4965	47·0	26475	21180	19000	1140000	60·00	12900	35	51220	41000	39000	1817000	46·59
4965	35·0	19715	15770	14500	1351000	93.17	12900	35	51220	41000	39000	1730000	44·36
6980	16·0	12670	10136	8700	901000	103·56	15200	20	34490	27590	24900	1321000	53·05
1620	......	......	......	......	......	......	2800	20	6350	5080	4660	310000	66·52
7860	35·0	31211	24968	22740	1737000	76·38	17800	40	80780	64600	60400	2634000	43·61
7560	59·0	50600	40500	38400	3192000	83·12	16200	59	108400	86700	82000	4348000	53·02
7550	15·0	12850	10280	9360	908600	97·07	16000	30	54450	43560	38400	2053000	53·46
160	......	......	......	......	......	......	1280	......	......	......	......	......	......
150	......	......	......	......	......	......	1260	......	......	......	......	......	......
60	......	......	......	......	......	......	550	......	......	......	......	......	......
60	......	......	......	......	......	......	550	......	......	......	......	......	......
......	......	......	......	......	......	......	......	......	......	......	......	......	......
3500	24·0	12250	9700	9220	......	......	4500	24	12250	9700	9220	......	......
5000	24·0	13614	10900	10000	714000	71·41	5000	24	13614	10900	10000	644200	64·42
4000	21·0	9530	7620	6700	670000	100·00	4000	21	9530	7620	6700	458000	68·36
......	......	326835	261294	239220	17913600	......	......	......	1176310	941330	875430	41843363	......
......	......	......	......	......	......	74·88	......	......	......	......	......	......	47·80

'The water-powers of the rivers through which the Georgian Bay canal passes present many varying and important features.

Their proper consideration requires careful study from their economic as well as physical aspect.

It is not a difficult problem to calculate the cost of developing any power, but its value, when developed, depends on whether a market for the power exists, or if it can be created. In the Ottawa and French river valleys there is, practically, no present demand for power. Much of late has been written of the value of water-powers for manufacturing purposes, but power is but one of the smaller items in the cost of most manufactured articles. The cost of a manufactured article is governed most largely by the cost of labour, cost of raw material and transportation of the raw material and finished product.

Before the development of the otherwise cheap powers of the Ottawa river can be decided upon, full information with reference to the amount and cost of raw material, of labour, and the transportation facilities, is required. Ultimately all the water-powers of the Ottawa and French river valleys will furnish motive power for some useful purpose. Their present value varies with the length of time remaining before the ultimate development is reached. If this length of time could be predicted, their absolute present value, as compared with steam or other motive power and their economic worth to the country, could be calculated. But a prediction of this kind is but little better than a guess where so many variables affect the result.

Aside from the pulp and paper manufacturing, for which there is an abundance of raw material which the river transports cheaply to the mill, there are but few manufactories that could now be expected to locate on the water-powers of the Upper Ottawa.

For pulp and paper mills these powers offer splendid sites. Their principal drawback is the lack of competition in the transportation of the finished product. Where weight is so great compared with its value, transportation plays an important part in the location of any manufactory of this type. Apart from the development of these powers for the pulp and paper business, no great likelihood exists of their 0being developed in the near future, except for possbile electric smelting or electrification of railways, chemical works, which are large users of power, might be advantageously placed at some of them.

The chief difficulty in developing the various powers is in connection with the construction of the necessary dams and head-works. Generally, each development requires the construction of a new dam entirely across the river. These dams would be sufficient for the development of the entire flow of the river, but usually a market is only available for a small portion of this, and the initial development would have to pay interest on the outside works for the total development until such time as a market for the total development was created. It might be stated, as a general principle, that the development of these powers requires an initial market for at least 50 per cent of the total available power before development is commercially feasible.

This statement is subject to some exceptions where the river is adaptable for smaller development, as in the case of the Chaudière at Ottawa, but the development of the powers by a number of small users, such as in the above, leads to extreme wastefulness and litigation.

The Chaudiere, the Chats, the Grand Calumet, Des Joachims, and the Rocher Capitaine are the big powers of the river below Mattawa. There are numerous other powers of lower capacity. Some of these, although offering sites from which power could be developed cheaper than steam, will hardly become commercial factors in the present generation. One other feature seriously retards the present development of the powers. The river is subject to great fluctuation from high to low water. Although it may not be exactly correct to valuate any power from the minimum conditions of

flow, still the head races require to be constructed of sufficient capacity under those minimum conditions, and therefore their size is usually much greater than would otherwise be necessary.

The present plans for the construction of the Georgian Bay canal entirely alter the general features of the river. For the purpose of lockage, the falls have been concentrated and all of the low rapids obliterated. Navigation requires the construction of dams across the head of most of these powers. These dams, built for navigation purposes, eliminate the greatest difficulty from the development of the water-powers, it being only necessary, in the majority of cases, to install machinery for the available market, extending as it increases. The partial initial development, per horse-power would, therefore, be but little more expensive than the unit cost per horse-power for the total development, whereas, as previously mentioned, the present development of the powers, except for very large initial consumption, is practically impossible. In addition, the needs of navigation require the elimination of extra high water by the construction of a system of storage reservoirs at the upper reaches of the river, this water to be released at low water period and eliminating extreme minimum conditions. This feature is described in detail in this report, under 'Storage.'

Ideal sites for the location of flour mills for milling in transit will also be available and, no doubt, many other manufacturers will be attracted by the combination of cheap power and transportation. The advantages of these two combined have been shown particularly at the Soo and Niagara. In neither of these cases can the power be considered as cheap as can be developed in other portions of the country. But the advantage of cheap transportation and local market has developed these before the other cheaper powers have been touched.

The construction of the canal will furnish one of the principal reasons for the development of the powers by giving cheap transportation both for the raw material and the finished product. The powers will be still better adapted for the manufacture of paper and pulp with a waterway both to the American and European markets.

It would seem advisable, in view of the above circumstances, that if there is a probability of the canal being constructed, that immediate control of the various water-powers be acquired by the Dominion government.

A study of the intimate relations between the proper development of the powers and the construction of the canal will show the truth of this statement.

The present system of dual control by the provinces of the bed of the river and control of the water for navigation purposes by the Dominion has led to many complications and retarded their proper development and has been the source of expensive litigation. These powers constitute one of the great natural assets of the Dominion and their proper development is one of serious importance to the entire community.

The table shown on page 292 has been prepared giving the governing features of the developments of present low water and the developments of the regulated low water after the canal is constructed. By a careful study, the contrast between the two is plainly apparent and even the most conservative cannot fail to be convinced of the enormous increase of power available after the canal is constructed.

The tabulated capital costs per electrical horse-power, are figured on electric power from the largest practical units. The estimates do not include anything for transmission lines and are subject to variation depending on the purpose to which the power is applied.

A study of the powers was conducted as follows:—

The position where best efficiency could be derived from the water was decided upon. The survey plans showing 5-foot contours, proved of great value. The effective turbine H.P. was calculated and the number of electrical units determined, the size of the power-house and other details.

The present development proposed for these powers might be criticized as not being the most economical, even for electrical generating plants, but developments have been projected to concur, where possible, with the plans of the canal as to situation of dams, etc., and hence a better contrast with the development which is proposed after the canal is constructed.

It must be borne in mind that the capital costs tabulated, are based on developments of the total low water flow and in each case as a combined property. A power company usually constructs the outer works for the ultimate capacity of the plant and installs only the necessary number of hydraulic and electrical units to supply the demand of the market at that time; additional units are added as the market increases and generally after some return has been made on the first investment.

A short description of the various sites follows, describing in more detail the larger powers. This will, doubtless, impart some idea of this enormous asset of the Georgian Bay Ship canal:

From the Montreal terminus to the Lake of Two Mountains, the two routes under consideration for canalization are.—

1st. Via Lake St. Louis and Ste. Anne de Bellevue.

2nd. Via Rivière des Prairies (Back river).

On the latter route, the Prairies lift will be the first power site situated about five miles from Bout l'Ile. The rapids here are impracticable for a present development, as the head of 8 feet is greatly reduced at high water. If the canal is constructed, there will be a minimum effective head available of 22 feet and a flow of 40,000 cubic feet per second. With these conditions, there could be developed 74,240 electrical horse-power. It is questionable whether 40,000 cubic feet per second, which is slightly less than the total regulated low water flow from the Lake of Two Mountains, could be utilized on the Rivière des Prairies channel as sufficient water would probably be required in the other channels to accede to riparian rights.

The Recollet lock will be situated about eight miles above the Prairies lock. From Cartierville to Sault au Recollet, a distance of five miles, there is a fall of 27 feet. There are several minor developments under small heads, but no large development has been attempted on acount of unfavourable conditions. The canal lift at the Recollet lock will be 35 feet and, in order to economically use this head, it is proposed to locate a power-house along the bank of the entrance canal about one and one-half miles above the lock. Allowing sufficient water for lockages during the busiest season, a flow of 8,000 cubic feet per second could be used to develop 74,240 electrical horse-power. It is questionable whether 40,000 cubic feet per second, not utilize the whole regulated low water flow, it is the most probable and economical when careful consideration is given to the location of the canal works.

The two lifts on the Rivière des Prairies will create very valuable water-powers, especially as being in the district of Montreal.

Proceeding by way of Ste. Anne, the first power will be located at Pointe Fortune, near Carillon, 49½ miles from Montreal. The present low water head is 13½ feet, which, with a discharge of 17,400 cubic feet per second, is capable of developing 19,300 electrical horse-power. After the canal is constructed, there will be concentrated here the fall of the series of rapids above, making a head of 40 feet, which with a regulated discharge of 43,950 cubic feet per second is capable of developing 148,000 electrical horse-power. This power would, undoubtedly, be of great value as being in such close proximity to Montreal, where the market for electrical energy is rapidly increasing.

The next power site is situated at Hawkesbury, which is 60 miles from Montreal and 10½ miles from the Pointe Fortune power just described. On the Quebec shore, the Hawkesbury Lumber Company have developed some 1 200 horse-power under an 8-foot head. Canal regulation works will maintain a maximum fall of 25 feet, but, allowing six feet for slope of the water surface in the 67 miles above, friction, losses,

&c., an effective head of 19 feet can be utilized and 71,800 electrical horse-power developed. The large cost of this development, as tabulated, is owing to the heavy expense in the construction of outer works, the main channels of the river being taken up by sluice-gates for the proper maintenance of the canal levels; also the head being comparatively low, the adoption of smaller electrical units is necessary. This improved power at Hawkesbury would most likely be used in different lumber and pulp manufactories for the district below Ottawa.

The next lift at the Chaudière falls is 126·8 miles from Montreal. There is at present a turbine installation of about 50,000 horse-power under heads varying from 16 to 27 feet. These present powers are being greatly improved by the construction of a massive stop-log dam across the river, just above the falls. The canal dam will, probably, be placed about three-quarters of a mile above the falls, and, in order not to interfere with the present interests, a development has been figured on with a twenty-foot head which will be the difference in the level between the water in the reach above Ottawa, and the water surface to be maintained by the power owners' dam. Hence, with a regulated discharge of 28,000 cubic feet will be an additional 45,000 electrical horse power available at the Chaudière after the canal is constructed. This increase of power would be welcomed, as even at the present time the supply of hydro-electrical power is insufficient.

By the erection of the canal dam, at Ottawa, the Deschenes rapids will be drowned out.

The Chats falls is the next power site situated twenty-eight miles above Ottawa and 155 miles from Montreal. A thorough study being made of a development here, it is proposed to raise the head water sufficiently to drown out the Chats rapids above. Under a 48-foot head, there is at present 43,300 horse-power available here. In contrast to this, the conditions when the canal is built, will be a regulated low water flow of 27,400 cubic feet per second which, with an effective head of 48·5 feet is capable of generating 113,500 horse-power. For both present and future developments, it is proposed to construct a canal head race, 2,100 feet in length on the Quebec side. The Chats falls are situated within comparatively short transmission distance of numerous cities and towns, which would, no doubt, flourish if the canal were built and consequently, greatly increase the demand for power.

Passing up the river twenty miles further, the Chenaux rapids are reached. The available power at present is, practically negligible owing to the fall being very small, but the canal will concentrate here a head of 35 feet and of 68,300 horse-power capacity. Besides the Chenaux lift being a power directly created by the canal the other sites on this reach of the river will be greatly increased in value. From the Chats to Pembroke there are long stretches of shallow rapids, &c., where frazil and anchor ice troubles would abound but which will be eliminated by the raised canal levels.

At mileage '183' the Ottawa river is divided into two channels by Calumet island. The south channel consists of a series of pitches and rapids, twelve miles in length. By the canal, these rapids will be concentrated into two lifts three miles apart, and of 35 feet each, called the Rocher Fendu No. 1 and the Rocher Fendu No. 2 with a total of 78,000 electrical horse-power available.

The Grand Calumet falls are situated on the north channel caused by Calumet island. In a distance of a mile there is a drop of 56 feet made up of a number of cascades of great turbulence. Taking the present extreme low water flow of 4,635 cubic feet per second, there could be developed here, 20,100 horse-power. As the proposed canal route will most likely be through the Rocher Fendu channel, it will be necessary to put a dam in the Calumet channel for the proper maintenance of the canal levels. Properly placed, this dam, together with the other canal works could be utilized to develop a most valuable power site, with the following governing conditions:—A maximum effective head of 69·5 feet and a regulated low water discharge

of 9,700 cubic feet per second, making an available capacity of 56,000 electrical horse-power. The Grand Calumet is an excellent site for a pulp and paper industry, as a large timber country is available through tributary streams situated short distances further up the river.

The next fall will be at Paquette, 209 miles from Montreal. At present there is a maximum available head of 16 feet, capable of developing 8,700 horse-power. Extensive works are necessary to obtain this power which presents a great contrast with the power which can be obtained after canalization. By the latter, there will be concentrated here a head of 20 feet, making available 24,900 electrical horse-power.

Culbute chute is a small power situated on the north channel caused by Allumette island.

Fifty-six miles from the Paquette lift are the Des Joachims falls, 266 miles from Montreal. With a head of 35 feet, the present low water capacity is 22,740 electrical horse-power. The available head after the canal is constructed will be 40 feet, developing 60,400 horse-power.

Eighteen miles further, or 284 miles from Montreal, are the Rocher Capitaine falls. This is another of the large powers of the Ottawa river. The present physical conditions are favourable to development. The river swings around a neck of land across which a canal head-race one and one-half miles in length could be constructed —thus, to utilize an effective head of 59 feet, and develop 38,400 electrical horse-power. The same scheme of development could be adopted after the canal is built. The available head would also be 59 feet but with the increased regulated low water flow of 16,200 cubic feet per second, a capacity of 82,000 horse-power could be obtained.

The next fall at Deux Rivières has a present maximum head of 15 feet, with a capacity of only 9,360 horse-power. This could only be developed at a large capital cost. The canal will concentrate here a fall of 30 feet, making 38,400 horse-power available.

The last three water-powers, viz.: Des Joachims, Rocher Capitaine and Deux Rivières, are situated within a stretch of 31 miles and would aggregate a total of 180,800 electrical horse-power after the canal is constructed, as against 70,500 horse-power if developed fully for present low water. It is not probable that any improvement of these sites would be attempted under present conditions, as the country in the vicinity is sparsely settled and the land is very rough.

From Mattawa to Lake Nipissing, the various lifts which will be created by the canal will not be available for power purposes as the water supply of the Summit will be practically required for lockages, and storage.

The water-powers of the French river are, at present, many in number but of small capacity. The Big Chaudière, Five-Mile rapids and the Dalles are the largest and most suitable for power purposes, especially so as the canal lifts on the French river will be concentrated at these three places.

The regulated flow on the French river, after the canal is constructed, will be the same as the present low water flow, which is more than sufficient for canal purposes, hence storage is not required.

An estimate of the cost of developing the Big Chaudière is not given, as the data necessary was rather incomplete.

Five Mile rapids are situated forty-five miles from North Bay; the total low water flow is 5,000 cubic feet per second. A total effective head of 24 feet and 10,000 electrical horse-power is available. The capacity of this power being the same before and after the canal is constructed, the cost of development with the canal built is decreased only by the cost of the dam, which would be borne by canalization.

The Dalles falls are situated about a mile from Georgian Bay. In order to obtain a head of 21 feet and utilize a low water discharge of 4,000 cubic feet per second, it is necessry to dam the four channels. Only 6,700 horse-power could be developed at Dalles falls.

There are many other features which are taken into account in the study and valuation of the water-powers, such as run-off flow at all stages, etc., etc., but these are given elsewhere and it is deemed unnecessary to repeat the same here.

The list shows that upwards of 1,000,000 horse-power can be developed along the Ottawa and French rivers by the improved regulated conditions proposed for canal purposes. It is doubtful if more than 150,000 horse-power at minimum conditions could be developed at present.

It might be urged that the development of the powers could be so governed that any development would be along the lines shown in the Georgian Bay canal plans, even though the construction of the canal were indefinitely postponed.

As previously shown, it would appear as if such a stipulation would seriously retard the development of the power, as the initial expenditure would be larger than almost any company could undertake.

The probability is that, with the present system the powers will not be developed for more than 150,000 horse-power, and that the capital cost per electrical horse-power at the out-going terminals of the power-house would average $75 per electrical horse-power.

With construction of the canal, this amount would be increased to 1,000,000 horse-power and the capital cost per horse-power exclusive of the works, which are constructed for canal purposes, would average $48 per electrical horse-power.

Considering the reduced price per horse-power resulting from the decreased capital cost and the improvement due to cheap transportation, it would appear that it would not be an improbable hypothesis as a basis of calculation to assume that the 1,000,000 theoretical horse-power would be developed in as short a time as 150,000 horse-power, under present circumstances.

Different methods might be followed in case of construction such as:—

1. The power might be leased on the basis of the reduced capital cost per horse-power of the development. The proceeds to be used in paying the interest on the investment and reducing the tolls of the canal. An annual rental of $5 per horse-power would result in an eventual revenue of $5,000,000 per year.

2. The power might be granted at nominal figures to attract manufactories from which the transportation of the raw material and manufactured articles would repay the privileges granted.

The regulated low water, which is the minimum flow to be maintained for canal purposes has been taken as the average of the lowest year, viz., 1877, and the storage necessary to maintain this flow is figured accordingly. Hence, it is fair to assume that the improved water powers will be able to operate to their full capacity for twelve months in the year.'

LEASES OR SALES OF WATER POWERS ON THE OTTAWA RIVER BY THE ONTARIO AND QUEBEC GOVERNMENTS.

An attempt has been made to collect all the information in this regard as well as that concerning all water lots conceded other than water-powers, sales of islands, reservation of beach lots, &c., and show the actual conditions in so far as affecting the river, on diagram maps with explanatory notes. Unfortunately, it has yet been impossible to get all the information together, and it may be given under the form of a supplementary report, should it be decided to proceed with the canalization of the river.

A brief statement, however, of the condition of the river, as regards the leases, options or sales of the water-powers in so far as our present information goes may be given.

The centre line or axis of the Ottawa river forms the division line between Ontario and Quebec from Carillon all the way up to and beyond Mattawa.

The water-powers along that stretch are under a dual control, each province disposing of the power on its side of the line to their best respective interests, excepting at the Chaudière falls, where the power is under federal control, and which is the largest developed power on the river.

The situation there is somewhat complicated. The original works did not form part of a comprehensive plan embracing the whole of the power available, and the development has taken place gradually by various interests, in a haphazard way. Some of the works are of poor character and allow a good deal of waste, and during the low water period, there is not enough flow to run at full capacity, and the scarcity of water is aggravated in winter-time by anchor ice.

The different powers and their present condition at the Chaudière may be summarized as follows:—

ONTARIO SIDE.

No.	Owner.	Title to Property.	Quantity of Electrical Horse Power.	Uses of Power.
1	Ottawa City		1,600 normally (3,000)	Pumping domestic water and fire protection.
2	Bronson's	Riparian Crown acre	2,600	Power sold to Ottawa Electric Co.
3	Ottawa Street Railway	Lessee Govt. Hydraulic lots Q and part of R and T.	2,600	Power used to drive Street Ry.
4	Ottawa Investment Company	Govt. water lots, S & part R	400	Power used to drive saw-works; sub-let to Ottawa Street Ry.
5	Ottawa Power Co.	Govt. water lots, U, V, W, X, Y and Z.	7,500	Power used in Concrete works.
6	Ottawa Electric Company	Govt. lots, K, L, M, N, O and P.	5,000	Power used to supply electric light and power.
7	J. R. Booth	Govt. lots, H, I and J	9,000	In pulp mills.
8	J. R. Booth	Govt. lots, B, C, D, E, F and G.	7,000	Saw-mills, &c.
	Total, Ontario side		35,700	

QUEBEC SIDE.

9	Ottawa and Hull Power Co.	Riparian and Quebec Govt.	7,000	Electric Light and Power in Ottawa and Hull.
10	E. B. Eddy	Riparian owner	14,000	Pulp and paper mills.
11	City of Hull	Brewery Creek	550	Pumping water and fire protection.
	Total, Quebec side		21,550	
	Grand total, Ontario and Quebec sides		57,250	

These developments have been a gradual growth from the time when all the powers were used for saw-mills. Large developments have been made on the old mill sites, and neither the head races nor the tail races are of sufficient capacity for the economical use of water.

At high water and the ordinary stage of the river in summer time all the plants run to their fullest capacity, but at other times during periods of low flow, power owners, especially on the Ontario side, are forced to close down, either completely or partially. In fact over-development has taken place, under conditions of flow and distribution which has been left unimproved, though attempts to do so have been made up to date without much success.

The present arrangement of hydraulic lots originated in 1851, before Confederation.

The existing government then caused a survey to be made of the Chaudiere and Victoria islands, which were situated in that part of Canada then called 'Upper Canada,'—which islands and surrounding property were vested in the Crown—and had the same subdivided into hydraulic and building lots, the hydraulic lots numbering twenty-five in all, and being designated respectively by the letters, B.C.D.E.F.G.H.I. J.K.L.M.N.O. and P, on Chaudiere island, and Q.R.S.T.U.V.W.X.Y. and Z. on Victoria island.

The leases which were drawn up in the subsequent years were with a view of developing one hundred and fifty horse-power at each lot, or three thousand seven hundred and fifty effective horse-power at the twenty-five lots, equivalent to five thousand theoretical horse-power.

At present at these twenty-five lots there is developed upwards of thirty thousand theoretical horse-power or over six times the original amount contemplated. The result is that at low water seasons considerable shortage occurs.

In the list of power owners given, Nos. 1 and 2 are not lessees from the government, but their rights are protected in the said leases, by clauses 7 and 12 which are respectively,

> *Clause 7.*—Nothing in these presents is to interfere with the right of Her Majesty or Her Successors, or the government of Canada, to permit the corporation of the city of Ottawa, to take out of the said Ottawa river, as it does at the present time, the supply of water required for the public uses and purposes of the said city and the citizens thereof, and to drive and propel efficiently the motors and machinery required for the proper distribution and service of the said water; and Her Majesty or Her Successors may, from time to time hereafter, give to the said corporation, for the uses and purposes aforesaid, authority and permission to extend its works, on such conditions as the minister may determine. A sufficient supply of water for all such uses and purposes being likewise hereby reserved.'
>
> *Clause 12.*—'It is also provided that nothing herein contained shall be deemed to diminish, later, take away or affect the riparian or other rights (if any) of any of the said lessees as proprietors of property not covered by these presents.

It is doubtful if the framers of the original leases ever supposed that anything approaching the present power development would be reached. Clause 3 relating to the quantity of water which the lessees are entitled to for each respective hydraulic lot reads as follows:—

> *Clause 3.*—The quantity of water which is hereby demised or intended to be demised to the lessees shall, subject to the conditions, provisos, reservations and limitations hereinafter mentioned and contained, in respect of each lot be sufficient to produce a force equal to one hundred and fifty horse-power. If, however, that force or power is not sufficient, efficiently to drive the machinery in use, of any mills or factories, which at the date of these presents are erected on such lot or group of lots adjoining each other, then the lessee or lessees may, subject to the said conditions, reservations, provisos and limitations hereinafter mentioned and contained, take and use such additional quantity of water as shall be sufficient, efficiently to drive the machinery thereof, which said additional quantity of water is also hereby demised to the lessees, subject as aforesaid to the said conditions, provisos, reservations and limitations hereinafter mentioned. And provided further, that if at any time, hereafter other and more extensive mills or factories of the same or of any different description, or for the same or any different purpose or purposes, be erected upon any one of the said lots or any one or more of a group thereof adjoining each other, or any additions or extensions upon any lot of a group of lots adjoining each other be added or made to the mills or factories now existing, then the lessee or lessees requiring a further additional

force of water efficiently to drive the machinery of such other additional or enlarged mills or factories may, subject to the conditions, provisos, limitations and reservations above referred to, take and use such additional quantity of water as may be necessary, efficiently to drive such machinery, which said additional quantity of water is hereby demised to the lessees, subject as aforesaid to the said conditions, provisos, limitations and reservations.'

It is apparent that although this clause provides for an extension of power in case 150 horse-power was unsufficient, that no such development as exists to-day was then contemplated by the lessor.

The original plan and all improvements since appear to have been designed with a view of automatically giving to each lot its proper proportion without the intervention of any one, but unfortunately such an ideal condition is practically impossible, and as a result in times of shortage certain powers whose natural position allow them are able to obtain more than their proper share. Many improvements have been initiated to relieve this, but none of them entirely successful.

Clause 8 of the leases was inserted to provide for such condition, when the Minister of Public Works has the power, when appealed to by any one of the lessees, to apportion the available water in equal proportion to each power owner according to the number of hydraulic lots leased to him. This clause reads as follows:—

'It is hereby agreed and declared by all the parties to these presents that, *interse,* all of the said hydraulic lots shall stand on an equal footing, and that each lot shall be entitled to an equal proportion of water, and it is therefore agreed and understood that in case of there being at any time or times a shortage or unsufficiency of water available efficiently to drive the machinery of any mills or factories which now are, or from time to time may hereafter be, erected on the said lots respectively, then the minister, when and so often as such shortage may happen, at the request in writing of any lessee affected by such shortage, may inquire into such alleged shortage, and if in his judgment the same be established, he may, if he sees fit, apportion to each lot as nearly as possible a one-twenty-fifth part of the available water or power which the lessee or lessees are entitled to under and by virtue of these presents, subject to the reservations, conditions, provisos and limitations herein contained, so that no lessee or lessees of any one lot shall have any undue advantage over another.'

The owners or power users at the Chaudière may be divided into three classes:—

1st. Those who are supplying the necessities of life and protection to property, such as the city of Ottawa and the city of Hull, which are dependent on the Chaudière power for water supply for domestic purposes and for fire protection.

2nd. Those who are supplying such necessities as electric light and electric power for the street cars. To this class would belong the Ottawa Electric Company, Bronson riprarian property, the Ottawa and Hull Power Company and the Street Railway Company.

3rd. Those using power in the manufacture of merchandise.

For the first two classes a shortage of water becomes a serious matter, and such shortages are likely to be felt more in the future, as the population increases and the different services have to be extended, if the present condition of the powers is not improved.

In 1904 and 1905 the Department of Public Works carried on an investigation to ascertain the condition of the powers at the Chaudière.

As the amount of water required and consumed varies from day to day and year to year, it is extremely difficult to describe conditions completely, but in March, 1904, the following conditions prevailed, as reported upon by Mr. Alexander McDougall.

The total flow of the river was nly 11,500 cubic feet per second. Of this, 500 cubic feet went to the Ottawa Water Works, 2,000 cubic feet to the Ontario power owners, 5,000 cubic feet to the Quebec Power owners and 4,000 cubic feet over the falls, wasting through the dam.

As the Ontario power owners normally require about 10,000 cubic feet per second it is seen that during that month they only obtained a little over 20 per cent of their requirement, and 80 per cent of their development was obliged to close down. The plants also at that time had the added disadvantages of anchor ice and low head.

In March, 1905, nearly all of the power owners on the Ontario side were forced to close down either completely or partially. The conditions were: The Ottawa Water Works were able to give a supply of water but their fire protection was poor, and at the time of an inspection by the fire underwriters it is said that the plant worked very poorly. The city have been trying to improve this condition by the building of a new tail race which will give them an increased head.

The Ottawa Street railway hydraulic development was closed down, running their steam plant. The Bronson riparian property was closed down, as well as the Ottawa Power Company. The Booth Pulp Mill closed down at 5 o'clock in the evening and started to run at 12 o'clock midnight.

The Ottawa Electric Company started at 5 o'clock and ran until 12 o'clock midnight. Both of these last mentioned plants were only able to run partially. The Ottawa Street Railway operated a steam plant, storage batteries, got some power from the Electric Light Company but gave a relatively inferior service. The E. B. Eddy Company on the Quebec side is reported not to have suffered greatly, and the Ottawa and Hull Power Company had at that time only installed about one-half of their plant.

These facts are enough to show the helpless condition of the powers at the Chaudière in time of shortage, and show the great necessity of applying a remedy without more delay. The fact that not only industrial firms may suffer, but that water supply and fire protection may be involved, should be a matter of great concern to the government and all other interested parties.

I understand that after practically several years of negotiations between the power owners, a decision has been reached to build a new dam which will somewhat improve conditions. But in times of extreme low water, difficulties will continue to exist unless some system of storage is established at the head-waters of the Ottawa river, restraining the flood waters, and releasing them gradually, thus increasing the average low water.

In 1904, Mr. George P. Brophy, Superintending Engineer, Ottawa River Works, was charged by the Department of Public Works to carry on an investigation with this end in view, and as his report—though made in connection only with the improvement of conditions for the industries depending on water powers—is intimately connected with the question of the storage problem in relation to the navigation scheme, the part referring to storage will be given here in extenso, as the information it contains is of great value.

> 'I have prepared, and transmit herewith, in addition to other maps, plans, profiles, etc., a key-map showing the location of the proposed reserves of water, as well as the location of the several reserve dams necessary to retain the water until needed for use during the seasons of low water in the fall and winter months.
>
> The general instructions given to the engineers in charge of parties, were: to make an exploratory examination and survey of the rivers and lakes within each district; to keep an official diary of each day's proceedings; to take levels where necessary and to establish proper bench-marks at suitable points; to take the velocity of rivers and streams and to estimate the discharge of same; to get the areas of proposed reserves of water; to record daily at 8a.m., 12 noon, and 6 p.m., readings of the barometer and thermometer during the whole period of the

work; to note particularly the points or sites where dams for preserving and controlling the water could most economically and advantageously be established; to note the kinds of timber and other material suitable for construction purposes, convenient or adjacent to the sites of the proposed dams; to measure the distances traversed; to secure the necessary data from which to estimate the cost of diverting the waters of lakes or rivers where necessary or advisable; to note particularly the damages which would or might result from 'flooding' by the construction of the improvements necessary in carrying out a successful system of water storage.

Owing to the late date at which work was commenced, and the early closing by frost of the lakes and streams in that northern district and the fact that a great portion of the country examined is practically unexplored territory the parties did not entirely cover the ground which it was intended they should, but notwithstanding these drawbacks, satisfactory work was done by each of the parties, and sufficient data has been obtained to establish the fact that, for a very reasonable outlay commensurate with the great benefits to be derived therefrom, a successful system of water storage can be established and maintained on the Ottawa river which will prove of very great advantage to navigation as well as of incalculable benefit to the lessees and users of water-power on the Ottawa river, from the city of Montreal westwards.

As will be seen by referring to the key-map before alluded to, a very large and important portion of the water-shed of the Upper Ottawa district has not been examined or surveyed. I allude to that portion of the country shown on the map as 'Grand Lake Victoria District' embracing what is known as 'Grand Lake Victoria' with its subsidiary lakes and streams. Through information obtained from lumbermen and their agents and explorers, and from the reports of surveyors employed by the Quebec government to define limit lines, &c., in that district, I have learned that Grand Lake Victoria discharges its waters into both the Ottawa and Gatineau rivers, the larger discharge being into the Ottawa. Until an examination and survey of the waters embraced in this district has been made, it is of course impossible to form an accurate estimate of the cost of reserve dams, &c., there, but judging from the information so acquired, and calculating, from maps supplied by the Crown Lands Department at Quebec—the area of water that can be reserved, I consider it very important that a party be sent there for the purpose of obtaining the necessary information so as to secure a reliable report on the feasibility and cost of constructing the works necessary to hold in reserve a portion of the water supplied to Grand Lake Victoria from the large water-shed to which it serves as a reservoir. While, as stated, not having the detailed information necessary, I have given an approximate estimate based on the information at hand, of the quantity of water which can be reserved there, and the probable cost of reserving it.

Another feature, and a very important one, to which I would particularly call attention, is the reservation of water in Lake Askikwaj, lying north of the Height-of-Land—whose waters discharge northward into Hudson Bay. As may be seen by referring to the key-map, the reservation of this large body of water would be a very important feature of the whole scheme, as may be judged when it is considered that the area of this reserve would be 84 square miles with a depth of 10 feet, besides which the ordinary flow of the River Askikwaj now passing into Hudson Bay, or the greater portion of it—would be permanently diverted into the Ottawa river by cutting a channel through the Height-of-Land at the point indicated by dam No. 7A. The construction of the two dams, No. 7A and No. 7B, would form part of this scheme, I may say in this connection that the work contemplated under this paragraph is a most important one and would greatly benefit the holders of timber limits in that district, by increasing the flow

of water from the Turn Back lake into the Kinejiskasatic river and thence into the Ottawa river, apart from the great benefit that would be derived by users of water for power purposes and for navigation on the lower reaches of the Ottawa river.

The difficulties encountered in the past ten or twelve years, especially by the government lessees as well as by other users of water-power at the Chaudiere falls at Ottawa, during the fall and winter months, caused by scarcity of water, have been very great. In former years and especially before the advent of electricity as a motive power and for lighting purposes, by far the greater portion of the water used was utilized by the parties mentioned in connection with their saw-mills and factories for the manufacture of lumber, &c., and as the logs and timber were floated to the mills and held in booms until sawn, these mills had of necessity to close down about the end of November in each year and remain until the month of April following, when the ice had left the river.

At the present time only two saw-mills are in operation, those of Mr. J. R. Booth, in Ottawa city, and a small mill owned by Mr. E. B. Eddy, in the city of Hull, where formerly large mills were operated by the former gentlemen and by Messrs. Perley & Pattie, Bronson & Company, Levi Young and A. H. Baldwin, in Ottawa city, and by Messrs. E. B. Eddy & Company, and Buell, Orr, Hurdman & Company, in the city of Hull.

All the power formerly used by these firms, with the exceptions mentioned, is now utilized in the development of electricity, for lighting, power and manufacturing purposes and as the quantity required for the first-mentioned purpose is much greater during the fall and winter months when the supply of water is at a minimum, than in spring and summer when the supply is ample, the benefit of any addition to the supply during these months is proportionately greater.

I may here mention the fact that in order to permit of the proper lighting of the city of Ottawa during the fall and winter months, the other users of water leased from the government, have had at times to fully close down their water gates and at other times to lessen the quantity of water used by them fully one-half, so as to enable the Ottawa Electric Company to supply requirements in that respect.

Taking the period of low water as extending from November 1 to March 10, or say 130 days, and the discharge of water at the Chaudiere falls to average 15,000 cubic feet per second over the period, the utilization of this reserve water should the scheme be carried out in its entirety, will increase that discharge by at least 60 per cent making ample allowance for evaporation and absorption which is less during the time stated than in the spring and summer months.

Attached hereto is a statement in detail showing the name of each 'Reserve,' its cost and the quantity of water in cubic feet which it will conserve. In estimating the cost of the reserve dams, I have assumed that the design to be adopted will be similar to those heretofore constructed on the Ottawa river and its tributary streams for a similar purpose.

In addition to the estimate cost as given, should be added the expenditure necessary to provide telegraphic communication between the several stations, I will submit, as soon as possible an estimate covering this service, as well as the cost of small station-houses for the employees who take charge of the works and their probable number and salaries, etc.

In conclusion I might mention the fact that nowhere on this continent that I am aware of can the same amount of expenditure for a like purpose insure as valuable results, and I cannot too strougly recommend the project to the consideration of the Honourable the Minister, and should he decide to go on with the works, I beg permission to suggest and recommend that the dams at Temiscaming (No. 1), Quinze lake (No. 4), and Barriere river (No. 5), be proceeded with as

soon as possible so as to give relief in some measure to the existing and ever increasing difficulties experienced by the lessees of government water lots, and others at the Chaudière falls and elsewhere on the Ottawa river.

Reserve Dam No. 1—At foot of Lake Temiscaming.

This dam will be located at the foot of Lake Temiscaming, a distance of about 240 miles from the City of Ottawa. The most favourable site for a reserve dam is at the head of an island situated immediately at the foot of this lake; the island divides the waters of the Ottawa river into two channels, known as the East and West channels.

The East channel is that through which the greater portion of the water discharges and in consequence, this portion of the dam will be the more difficult and costly although not much longer than that required for the West channel.

The total length of dam from the shore on the Ontario side of the river to that on the Quebec side and across a portion of the island mentioned, will be about 1,100 feet, and the cost will be approximately $70 per lineal foot or say $77,000.00.

This dam will be designed to retain a reserve of water of 125 square miles in area and 8 feet in depth.

The level at which it is intended to hold this water is 5 feet 9 inches below the extreme high water level in this lake, and as ample provision will be made for the free discharge of the surplus water during the season of extreme high water, no land damages will result by holding the water for a longer period than usual on the portions of land now flooded during the time of high water.

(Reserve capacity 27,878,400,000 cubic feet of water.)

Reserve Dam No. 2—At head of Gordon Creek.

There is at present a dam at the head of Gordon creek, which was built, owned and controlled by the late Alex. Lumsden, lumber merchant, who also erected saw-mills on the creek. The mills are still in operation and the whole property is still in the estate of the deceased owner.

The greater portion of all logs and other products of the limits in the Kippewa district, are towed to the head of Gordon creek and floated down same, a distance of 8 miles, into the Ottawa river which it enters immediately below the site of proposed reserve dam No. 1, at the foot of Lake Temiscaming.

The proposed dam (No. 2) would be located at or immediately below the present dam and would be 240 feet in length which, at a cost of $22 per foot would require an expenditure of $5,280.

Reserve Dam No. 3—At foot of Kippewa Lake and head of Kippewa River.

This dam will be located immediately below the site of the present dam, (which is owned and controlled by the estate of the late Alex. Lumsden) where the waters of Kippewa lake flow into the Kippewa river and thence into Temiscaming lake, 28 miles from its lower end.

The dam required here will be about 200 feet in length, and will cost about $22 per lineal foot or $4,400 in all.

The reserve of water controlled by dams Nos. 2 and 3 above mentioned will cover an area of 110 square miles and will have a depth of 6 feet.

(Reserve capacity 18,399,744,000 cubic feet of water.)

Reserve Dam No. 4—At foot of Quinze Lake.

This dam will be located at the foot of Quinze lake and about 18 miles distant from the head of Lake Temiscaming. It was found that the most suitable site for a dam to retain and control the waters of this lake as well as the waters of

Lake Expanse, is near the head of two large islands situated at the outlet of Quinze lake where the water enters into the Quinze rapids, thus necessitating the closing of the three channels formed by these islands and the main shores on either side; the main or centre channel will require a dam 2,100 feet in length, the North channel, a dam 250 feet in length, and the South channel, a dam 600 feet in length, making in all 2,950 feet of dam, which, at $20 per running foot would necessitate an expenditure of say $59,000. The area of water that would be controlled by this dam is 96 square miles and from information so far obtained, a reserve of this area with a depth of not less than 5 feet would cause but little damage, which damage is estimated at this point, say $62,000.

(Reserve capacity, 13,381,632,000 cubic feet of water.)

Reserve Dam No. 5, on Barriere River.

(Within the limits of timber berth No. 3, range 2.)

The next site at which a reserve dam can be constructed with advantage, is at a point on the Barriere river, near the foot of Abikoba lake, distant about 16 miles from the last mentioned dam (No. 4).

A retaining dam at this point would hold in reserve 35 square miles of water, with a depth of 10 feet.

The dam would be 680 feet in length and would cost $22 per lineal foot, or say $15,000. The damages resulting from flooding timber lands would not exceed $3,000, making the total outlay for this station say $18,000.

(Reserve capacity, 9,757,440,000 cubic feet of water.)

Reserve Dam No. 6, on Ottawa River.

(Within the limits of timber berth No. 8, range 3.)

This dam would be located on the main Ottawa river, about six miles above its entrance into Lake Expanse and will be distant about 40 miles from dam No. 4 at the foot of Quinze lake. It will be about 850 feet in length and will cost $28 per lineal foot, or say $24,000. It will hold in reserve 25 square miles of water, 10 feet deep. It is estimated that the damage to small timber, &c., would not exceed $3,000, or say a total expenditure of $27,000 at this point.

(Reserve capactiy, 6,969,600,000 cubic feet of water.)

Reserve Dam No. 7, below Turn-back Lake.

This dam will be located on the Keewagama river or outlet of Turn-back lake, and will be distant from dam No. 6, last-mentioned, about 100 miles by water. It will retain in reserve about 48 square miles of water, with a depth of 10 feet. The dam will be about 275 feet in length and will cost about $30 per foot, or $8,250, in addition to which upwards of 3,500 cubic yards of rock will have to be removed, at a cost of say $2.50 per cubic yard, or say $8,750, to which may be added as damage for flooded timber, say $2,500, making the total outlay at this point $20,000.

(Reserve capacity, 13,381,632,000 cubic feet of water.)

Channel and Reserve Dams Nos. 7 A and 7 B—Askikwaj Lake.

By cutting through the summit level on the 'Height-of-Land,' the waters of 'Askikwaj,' 'Kia-na-uti-sik,' 'Wiquas-ko-paug,' 'Long Lake,' &c, that now discharge into Hudson Bay, can be diverted into Turn-Back lake, and thence into the Ottawa river.

The excavation will be through clay, will be one mile in length, and will necessitate the removal of about 200,000 cubic yards of material, the cost of which should not exceed 20 cents per cubic yard, or $40,000.

A retaining dam (No. 7 A) will be required to control the outlet into Turn-Back lake; this dam would be 650 feet in length and would cost $30 per foot or say $19,500.

Another retaining dam (No. 7 B) would be required for the same purpose, at the outlet of Askikwaj lake, 675 feet long, and the cost would be $25 per foot, or say $16,875, thus making the total outlay $76,375 for the work necessary to form and control this important reserve of water.

The area of water that could be reserved by the carrying out of this scheme would be 84 square miles, with a depth of 10 feet, besides which important reserve, the continuous flow of water from Turn-Back lake into the Ottawa river would be more than doubled.

(Reserve capactiy 23,603,712,000 cubic feet of water.)

Retaining Dams, &c., Grand Lake Victoria.

For reasons mentioned in paragraph 3—the engineer in charge of party No. 3 did not succeed in reaching Grand Lake Victoria, but from information acquired, as stated therein, I am of the opinion that the works necessary to secure a reserve of water in that lake will not exceed $75,000, and as the area of said reserve would not be less than 150 square miles, with a depth of eight feet, the cost would not, in my opinion, be excessive when the immense benefits that would be derived from the use of so large a reserve of water are considered.

(Reserve capacity 33,454,080,000 cubic feet of water.)"

SUMMARY OF COST, &c.

Name of Reserve.		Estimated Cost. $ cts.	Capacity in Cubic Feet.
Temiscaming lake,	Dam No. 1	77,000 00	27,878,400,000
Kippewa lake,	Dams Nos. 2 and 3	9,680 00	18,399,744,000
Quinze lake,	Dam No. 4	59,000 00	13,381,632,000
Barriere river,	Dam No. 5	18,000 00	9,757,440,000
Kinejiskasatic,	Dam No. 6	27,000 00	6,969,600,000
Turn Back lake,	Dam No. 7	20,000 00	13,381,632,000
Askikwaj lake,	Dams Nos. 7A and 7B	76,375 00	23,603,712,000
Grand Lake Victoria	(roughly approximate)	75,000 00	33,454,080,000
		362,055 00	146,828,240,000
Add 10 per cent for contingencies		36,205 50	
Total estimate of cost		398,260 50	

These storage dams as proposed by Mr. Brophy would not only be of great benefit to the Chaudière plants but would also greatly enhance the value of the undeveloped water powers along the Ottawa river. In the Chaudière case, at the present time, there is about 57,350 horse-power developed, requiring 18,000 cubic feet of water per second, but the present power houses have been designed for larger developments, and when the Ottawa and Hull Power Company put in their other wheels there will be nearly 67,000 theoretical horse-power development, requiring 21,000 cubic feet per second. It is calculated that the proposed dam to be built by the power users, aided by the storage system described by Mr. Brophy in such years as 1903-4 will give a mininum flow of 19,400 cubic feet per second. This will not quite supply the demands during the low period, but remembering that in 1903-4 the power users received only 7,500 cubic feet per second during the lowest water, and taking into account also the state of over-development which exists, it will be seen that the proposed improve-

ments if carried out, will largely increase the present power, though it will not permit of any extensions of the present development.

It must not be forgotten, however, that any project to improve the conditions of a river for industrial purposes, must take into account the question of navigation, if there is a possibility of the waterway being developed in the future for transportation purposes. It is of the greatest importance to the country that navigation interests be safeguarded on all streams, which may ultimately form part of a cheap transportation system.

The Ottawa river, particularly, should be carefully guarded in this respect. Opinions may differ as to the advisability of canalizing the river and incurring heavy expenditure at the present time, but its possibilities as a future national transportation route and highway of commerce, cannot be disputed. No more obstacles than already exist, should be placed in the way, and future navigation interests must take precedence, and govern the general lines of every new undertaking and agreement made as to the rights and privileges granted. Fortunately in the particular case of the Chaudière, the new proposed industrial dam will not interfere in any way with the adopted navigation scheme, as the canal leaves the bed of the river some distance above the falls, and passes back to the City of Hull, where suitable locations for the two locks required to overcome the difference in level are found. By doing this the nest of industrial establishments at the Chaudière is not disturbed in the least by the proposed navigation and many difficulties are avoided.

If the power dam is built in the location intended, no doubt it will be possible to approve of it, as the navigation dam is placed some distance above, where splendid power will also be created. As to the creation of storage reservoirs to improve the powers during periods of low water, the project may also be approved, as it is intimately connected with the requirements of the navigation system under study, as shown in other parts of this report.

But, should the canal be built, any storage system must be controlled, first in the interests of navigation. It should be undertaken as a government work, controlled entirely by the government, and developed gradually in the best interests of both navigation and industry.

I, therefore, earnestly recommend again, that all designs for the improvement of the Chaudière, as well as all requests for the granting of privileges at any place on the streams proposed to be utilized for the deep waterway, be submitted and receive the approval of a commission of engineers within the department, composed of the district engineers and the engineer in charge connected with the canal survey, before any building or any grant is sanctioned by the government, and in no agreement should it be obligatory on the government to give any portion of the water available to the mill owners except after the purposes of navigation have been supplied.

Rather extended details have been given in regard to the conditions of the Ottawa river at the Chaudiere, on account of its great importance as an industrial centre depending on the flow of the river.

Elsewhere, the river may be said to be relatively free for navigation purposes, though a great number of water lots for power and other purposes have been granted by both the Ontario and Quebec governments.

In case of the construction of the canal it will be necessary to have full information as to these grants. Preliminary steps have been taken to collect all the information available, and show on a special map all the land reserves made by the provincial governments along the Ottawa river, all the water lots and water power privileges granted, all islands sold, &c. The difficulty of getting this information together in a complete and comprehensive form is very great, and it will form part of a supplementary report. I may here, however, mention a few of the most important grants made in relation to proposed water-power developments.

Hawkesbury west.—By Ontario government. A water lot containing eighteen and a half acres at the head of the islands in the Long Sault rapids on the River

Ottawa, immediately in front of lots 11 and 12 in the 1st concession of West Hawkesbury; granted to Robert Hamilton, of Quebec, and Hon. John Hamilton of Hawkesbury Mills.

Grant dated December 15, 1865; Ref. No. 28140; sale No. 28499.

By Crown leases Nos. 1735 and 1736, four water lots containing in all about 71 acres were leased by the Ontario government to the Metropolitan Electrical Company of Ottawa, situated in front of parts of lots 20, 21 and 22 in the 1st con., Ottawa front, of the township of Nepean, in the county of Carleton and province of Ontario. This was leased with privilege of renewal subject to provisions of the Act 61 Vic. Cap. 8, and also subject to conditions as to development of water-power, and to rights of Dominion government to control navigation on the Ottawa river.

In January, 1905, the Ontario government granted to Joseph Kilgour, et la. part of lot 14 (35 acres and of lot 15, con. A. township of Clara, together with water-power at Deux Rivières rapids. This was leased for ten years at fixed rental subject to conditions under water-power regulations, timber and minerals reserved.

Some land and water-power at Chaudiere rapids on the French river were leased in 1904 to certain parties, subject to certain conditions, but this lease was cancelled by Ontario government Order in Council, December 14, 1906.

The Quebec government have conceded several land and water lots in the Chats Rapids district for power and other purposes, and also at different other places on the Quebec side of the river. It would be too long to enumerate these here. Several applications have been made for the powers at Des Joachims, Rocher Capitaine, and other places which have not yet been granted.

In all the waters utilized for the proposed waterway, it has been ascertained that a large number of islands which exist have been disposed of by the two governments. In some cases, sales or leases have been made subject to the rights of the Dominion government to overflow these lands for navigation purposes. In some other cases this stipulation is not mentioned.

Under the project submitted, a great number of these islands are necessarily flooded, and there will be numerous claims in this connection as well as for water-power privileges destroyed. It has been found a difficult matter to arrive at a correct estimate of the damage in relation to this, but the amounts included in the estimated cost make ample provision, I believe, for possible fair and just claims.

NOTE.—Since the foregoing was written the construction of a new power dam at the Chaudière falls has been commenced, and tenders have been called for the construction of reserve dam No. 1 mentioned in Mr. Brophy's report, at the foot of Lake Temiscaming.

LUMBER INTERESTS AND FLOATING OF LOGS.

On the rivers utilized for the proposed waterway—the French, the Mattawa and the Ottawa—lumbering operations are carried out on a large scale. The Ottawa is the great lumbering river of the region and logs are floated down from the upper reaches and tributaries in very large quantities. The canalization of these rivers for through transportation from the Great Lakes to the Ocean will necessitate a change in the present methods of handling the logs, and a shifting of base in manufacturing the output into lumber. The cutting of timber will also have to be regulated by some understanding between the federal and provincial governments interested, as the conservation of forests at the sources of the streams is a vital question related to storage of waters and mitigation of floods, for navigation purposes, and also for the prevention of extreme low flow at certain periods of the year affecting so many lumber and water power interests.

In the early days of the lumbering business, before railway facilities were available, Ottawa, then called Bytown, became the principal point on the Ottawa river for

the manufacture of sawn lumber, owing to its favourable position in respect to transportation facilities, being at the head of the navigation afforded by the construction of the small Grenville and Carillon canals and the Lachine canal between Montreal and Ottawa, and thus giving easy access to an ocean port.

As population and railway facilities increased, local as well as new foreign markets became available, and the conditions of manufacture changed gradually. Large mills were built and industries established at the mouths of the principal tributaries of the Ottawa, notably at Arnprior, Braeside and Pembroke, above Ottawa and at Rockland, Hawkesbury and Calumet below the city, where modern transporta tion facilities were available.

Notwithstanding these changed conditions, the territory tributary to the Upper Ottawa, from which logs are taken, still lacks the means for reaching the markets. Therefore, all logs have to be floated down in big drives, caught at certain points by booms, assorted and towed to the various mills located at the points mentioned.

The expenses incurred in getting the logs to the different mills are necessarily very great, apart from the losses incurred by the thousands of logs which strand or are piled high up on rocks in rapids, &c., during the drives. For the amount of lumber interests depending on the Ottawa river, very few improvements have been made by the lumbermen to facilitate their business. As the timber gets scarcer and further away from the centres of manufacture, greater care will have to be exercised in logging and the streams will have to be improved in order to decrease the losses and maintain fair profits.

As it is necessary now for some of the lumbermen to carry two years' cut of logs ahead, in order to be sure to have sufficient logs to keep the mills supplied, this requires a very large outlay. A conservative estimate of the investment would probably mean not less than $10,000,000 annually.

The towing on the river is done by the Ottawa Improvement Company, which owns all the steamers, tugs and booms, and handles annually between three and four hundred million feet of logs, pulpwood, cedar, &c., from which they derive a relatively large revenue. It is understood, however, that the company is a combination of the lumber interests, and the revenue must simply approximate the cost of the service.

It is stated that prior to 1885 very few logs were brought down that would not average 100 to 150 feet of sawn lumber. To-day the average output of a log approximates only 50 feet.

In addition to the logs there are large quantities of small spruce for pulpwood, cedar, etc., brought down which add to the superficial area of the tows and to the difficulties of handling. On the lower Ottawa there is handled annually about 100,000,000 feet, including pulpwood.

Since 1894 the output of the mills have not varied to any extent as will be seen, the annual production being as follows:—

	Feet B.M.
1894	538,000,000
1895	627,000,000
1896	614,000,000
1897	728,000,000
1898	633,000,000
1899	532,000,000
1900	538,000,000
1901	611,000,000
1902	614,000,000
1903	557,000,000
1904	565,000,000
1905	539,000,000
1906	475,000,000

As already stated the construction of the Georgian Bay Ship canal will considerably affect the present methods of handling the lumber industry. The logs cannot be permitted to float down loose for that part of the river which will be utilized for the waterway. Either the logs must be rafted above Mattawa, or at the mouth of the tributaries and taken down through the locks to their destination, or the mills must discontinue to manufacture at the different centres under present conditions, and move their mills to the mouths of the various tributaries.

During the first years of the operation of the canal, assuming that its traffic will develop gradually, the passage of rafts through the locks will be possible only until such time as the freight tonnage will have so increased that the rapid lockages of vessels would be interfered with and delayed by using the locks to pass the logs.

Then the establishment of the mills at the head of the Ottawa river section of the canal and at the mouth of the tributaries would be a necessity.

This, of course, would mean a decentralization of the lumber interests as they now exist, and, no doubt, the direct and actual cost of manufacture would be somewhat increased, as mills would probably have to be maintained on the various tributaries, adding to the staff of management.

On the other hand there would be considerable saving in time in the sawing of the logs of at least a year's outlay. An increased market would be created for the output and refuse of the mills, and facilities afforded for operations as near as possible to the base of supply. The present cost of towing and sorting would place the lumber alongside vessel or car as the case may be, without such a large percentage of loss in transit, as now exists under present conditions. It is believed that the proposed navigation would be ultimately a saving to the lumber interests.

Large areas of hardwood which have been left standing and which are practically valueless now owing to lack of transportation facilities, would be opened up. Cordwood, bark, etc., would be a much more valuable commodity owing to the cheapness of transport afforded.

It is fair to assume, that whilst the development of the waterway would mean the disappearance of the loose logs and tows, on the Ottawa river, it will prove of undoubted value to the limit owners and manufacturers of lumber generally.

It will mean, better facilities for handling the logs in the upper reaches of the river on account of the improved storage and control of flood waters in relation to the canal scheme, less losses in transit, quicker and cheaper transportation, extended markets, etc.

The question, however, of regulating severely the cutting of the timber in the uplands as mentioned at the beginning of this article, must not be lost sight of.

A more systematic exploration and protection of the forests than has been the case generally, must be arranged between all the interested parties.

The best of storage systems with a view of abating the floods and preventing extreme low discharges, in aid of navigation and industries, can only be partially successful if not worked in conjunction with the forests.

All the studies made by the best of authorities point out that forests at the sources of the streams are veritable storage reservoirs, and without them no artificial remedy can be either adequate or permanent.

In a denuded forest, water drains much more quickly to the natural basins, carrying much more sediment than if flowing slowly under forest cover. Erosion takes place and decreases the utility of reservoirs by sedimentation, and this must be prevented if reservoirs are to be of permanent benefit. This can be done only by conserving the forests or by reforestration.

The importance of this is shown further in the report regarding the possibility of control of the flood waters of the Ottawa river by storage reservoirs.

Reverting to the question of logs, the same conditions will prevail on the Mattawa and French rivers.

On the Mattawa it is possible that very little timber will be left to cut by the time the canal can be completed. On the French all logs and timber are floated and towed to the mouth, then to be sawn into lumber or towed to other mills on Georgian Bay or across Lake Huron to Michigan. Charges for towing there, seem to be greatly in excess of those that prevail on the Ottawa.

Other conditions, however, to a large extent are somewhat similar.

Therefore, it may be said, that the construction of the waterway on these rivers, would present equally as favourable conditions to the lumber interests as on the Ottawa, with the addition that a large number of logs that are now towed across Lake Huron to Michigan would be manufactured into lumber in Canadian territory.

DISTANCES.

Taking Port Arthur or Fort William as a starting point, the distance to Montreal via the proposed waterway is 934 miles; via Lake Erie and the Welland canal, 1,216 miles; via Buffalo and Erie canal to New York, 1,358 miles; giving a difference in favour of the projected route of 282 miles as compared with the existing St. Lawrence route, and of 424 miles as compared with the Buffalo-New York route.

Comparing the distance from Fort William to Liverpool via Montreal and via New York, we have:—

	Miles.
Fort William to Liverpool, via Georgian Bay canal..	4,123
" " " " New York..	4,929

giving a difference of 806 miles in favour of the Georgian Bay ship canal—Montreal route.

The following interesting tables of comparative distances, have been carefully prepared. These tables are also given on Plate No. 2, showing various water and railway routes.

TABLE OF SAILING DISTANCES IN STATUTE MILES.

—	Liverpool.	Sydney.	Quebec.	Montreal.	Prescott.	Kingston.	Toronto.	New York.	Buffalo.	Port Colborne.	Cleveland.	Toledo.	Detroit.	Goderich.	Owen Sound.	Collingwood.	Midland.	Victoria Harbour.	Depot Harbour.	Byng Inlet.	Key Harbour.	French River	Chicago.	Milwaukee.	Escanaba.	Sault Ste. Marie.	Duluth.
Fort William	4405	2050	1377	1216	1097	1039	904	1358	863	847	712	662	605	510	515	533	540	541	516	501	500	494	687	621	497	273	196
	*4123	1768	1095	934																							
Duluth	4527	2172	1499	1333	1219	1161	1026	1480	985	969	834	784	727	632	637	655	662	663	638	623	622	616	809	743	619	396	
	*4245	1890	1217	1056																							
Sault Ste. Marie	4132	1777	1104	943	824	766	631	1085	590	574	439	389	332	237	242	260	267	268	243	228	227	221	414	348	224		
	*3850	1495	822	661																							
Escanaba	4241	1886	1213	1052	933	875	740	1194	699	683	548	498	441	349	363	381	388	389	364	349	348	342	277	192			
	*3971	1616	943	782																							
Milwaukee	4365	2010	1337	1176	1057	999	864	1318	823	807	672	622	565	473	487	505	512	513	488	473	472	466	85				
	*4095	1740	1067	906																							
Chicago	4431	2076	1403	1242	1123	1065	930	1384	889	873	738	688	631	539	553	571	578	579	554	539	538	532					
	*4161	1806	1133	972																							
French River	4089	1734	1061	900	781	723	588	1042	547	531	396	346	289	174	99	110	109	110	75	31	21						
	*3629	1274	601	440																							
Key Harbour	4095	1740	1067	906	787	729	594	1048	553	537	402	352	295	180	98	108	104	105	71	25							
	*3650	1295	622	461																							
Byng Inlet	4096	1741	1068	907	788	730	595	1049	554	538	403	353	296	181	87	95	95	97	63								
	*3660	1305	632	471																							
Depot Harbour	4111	1756	1083	922	803	745	610	1064	569	553	418	368	311	196	77	80	82	83									
	*3704	1349	676	515																							
Victoria Harbour	4136	1781	1108	947	828	770	635	1089	594	578	443	393	336	221	73	58	6										
	*3739	1384	711	550																							
Midland	4135	1780	1107	946	827	769	634	1088	593	577	442	392	335	220	72	57											
	*3738	1383	710	549																							
Collingwood	4128	1773	1100	939	820	762	627	1081	586	570	435	385	328	213	48												
	*3739	1384	711	550																							
Owen Sound	4110	1755	1082	921	802	744	609	1063	568	552	417	367	310	195													
	*3728	1373	700	539																							
Goderich	3927	1572	899	738	619	561	426	880	385	369	234	184	127														
	*3803	1448	775	614																							
Detroit	3800	1442	769	611	492	434	299	753	258	242	107	57															
Toledo	3795	1437	764	606	487	429	294	750	255	237	99																
Cleveland	3717	1359	686	528	409	351	216	650	175	159																	
Fort Colborne	3558	1200	527	369	250	192	57	517	22																		
Buffalo	4066	1222	549	391	272	214	79	495																			
New York	3571	910	526	457	456	404	495																				
Toronto	3531	1173	500	342	223	165																					
Kingston	3370	1012	339	181	62																						
Prescott	3308	950	277	119																							
Montreal	3189	834	161																								
Quebec	3028	673																									
Sydney	2624																										

NOTES.—Below Lake Erie, the distances to New York given in the above table are computed as follows:—

From Sydney via the Atlantic Ocean; from Quebec and Montreal via the Richelieu and Lake Champlain route; from Prescott, Kingston and Toronto via the Oswego and Erie canals and Hudson River route.

The "*" mark the distances via the Georgian Bay Ship Canal route.

All distances are given in statute miles; for nautical miles, divide by 1·15.

TABLE OF CANALS ON UNITED STATES ROUTE.

Name of Canal.	Waters Connected.	Terminal Points.	Length of Canals.	Locks.				
				Number.	Length.	Width.	Depth on Sill.	Lockage.
			Miles.		Feet.	Feet.	Feet.	Feet.
Sault Ste. Marie....	St. Mary's River..............	Sault Ste. Marie, Mich..........	2	2	515 800	60 100	16·0 20·5	18·0
Erie..............	Lake Erie and Hudson River....	Buffalo and Albany............	352	72	110	18	7·0	660·6
			354	74	....	....	....	678·6

TABLE OF CANALS ON PROPOSED NEW CANADIAN ROUTE.

Name of Canal.	Waters Connected.	Terminal Points.	Length of Canals.		Locks. Number		Length.	Width.	Depth on Sill.	Height of lift	
			Miles.	Miles.			Feet.	Feet.	Feet.	Feet.	Feet.
Alternative routes. Montreal	Montreal harbour and Verdun basin	Montreal harbour	0·50	*	1	*	650	65	22	34	*
Verdun	Verdun basin and Lake St. Louis	Verdun-Lachine	5·00	......	1	....	650	65	22	18	......
Ste. Anne	Lake St. Louis and Oka lake	Ste. Anne	0·75	......	1	....	650	65	22	5	......
*Prairies	*River St. Lawrence and Ottawa river	*Riviere des Prairies	......	*1·00	....	*1	*650	*65	*22	......	*24
*Recollet	*Ottawa river and Oka lake	*Sault au Recollet	......	*11·75	....	*1	*650	*65	*22	......	*35
Pointe Portune	Oka lake and Ottawa river	Pointe Fortune	2·25	2·25	1	1	650	65	22	40	40
Hawkesbury	Ottawa river	Hawkesbury	1·75	1·75	1	1	650	65	22	25	25
Hull	" .... and Lake Deschenes	Gilmour's mill—Tetreauville	1·50	1·50	2	2	650	65	22	55	55
Chats	Deschenes lake and Chats lake	Pontiac bay—Chats rapids	1·25	1·25	1	1	650	65	22	50	50
Chenaux	Chats lake and Ottawa river	Chenaux island	0·75	0·75	1	1	650	65	22	35	35
Rocher Fendu No. 1	Rocher Fendu lake and Ottawa river	Flat rapids	0·75	0·75	1	1	650	65	22	35	35
Rocher Fendu No. 2	Ottawa river	Muskrat rapids	0·50	0·50	1	1	650	65	22	35	35
Paquette	Coulonge lake and Allumette lake	Spottswood ferry—Paquette rapids	0·50	0·50	1	1	650	65	22	20	20
Des Joachims	Ottawa river	Des Joachims	0·25	0·25	1	1	650	65	22	40	40
Rocher Capitaine	"	Rocher Capitaine	1·75	1·75	2	2	650	65	22	60	60
Deux Rivieres	"	Deux rivieres rapids—Trou rapids	1·50	1·50	1	1	650	65	22	30	30
Mattawa	" and Mattawa river	Mattawa	0·75	0·75	1	1	650	65	22	10	10
Plain Chant	Mattawa river	Plain Chant Chute power house	0·25	0·25	1	1	650	65	22	30	30
Les Epines	"	Les Epines rapids—Larose rapids	0·25	0·25	1	1	650	65	22	17	17
Paresseux	" and Talon lake	Lower Paresseux rapids—Sand bay	3·00	3·00	4	4	650	65	22	120	120
North Bay	Trout lake and Lake Nipissing	Three Sisters island—Rocky point	3·50	3·50	1	1	650	65	22	29	29
Chaudiere	Lake Nipissing and French river	Chaudiere falls	0·25	0·25	1	1	650	65	22	24	24
Five-mile rapids	French river	Five-mile rapids	0·25	0·25	1	1	650	65	22	24	24
Dalles	" and Georgian bay	French river village	0·25	0·25	1	1	650	65	22	22	22
		Totals	27·50	34·00	27	26	....	....	......	758	760

NOTE.—The "*" shows alternative routes, and when at the head of a column, it denotes that all figures in such column relate to alternative routes.

TABLE OF CANALS ON PRESENT CANADIAN ROUTE.

Name of Canal.	Waters Connected.	Terminal Points.	Length of Canals.	Locks.				
				Number.	Length.	Width.	Depth on Sill.	Lockage.
			Miles.		Feet.	Feet.	Feet.	Feet.
Sault Ste. Marie....	St. Mary's River..............	Sault Ste. Marie...............	1·13	1	900	60	20·2	18·0
Welland...........	Lake Erie and Lake Ontario.....	Port Colborne—Port Dalhousie...	26·75	26	270	45	14·0	326·7
Galops............	River St. Lawrence............	Galops Rapids—Iroquois........	7·33	3	270	45	14·0	15·5
Rapide Plat........	" "	Rapide Plat—Morrisburg........	3·66	2	270	45	14·0	11·5
Farran's Point......	" "	Pt. Avoyon—Farran's Pt........	1·00	1	800	45	14·0	3·5
Cornwall..........	" "	Dickinson's Landing—Cornwall...	11·00	6	270	45	14·0	48·0
Soulanges.........	" "	Coteau Landing—Cascades Pt....	14·00	5	280	46	15·0	84·0
Lachine...........	" "	Lachine—Montreal.............	8·50	5	270	45	14·0	45·0
			73·37	49	....	....	....	552·2

22 FOOT NAVIGATION PROJECT.

Description.	Length of Canals.	Length of improved channel.	Length of free navigation.	Total length.	Total Time.
Via	Miles.	Miles.	Miles.	Miles.	Hours.
French, Mattawa, and Ottawa rivers, and Lake St. Louis to Montreal...	27·5	55·5	357·0	440·0	70
Via French, Mattawa, Ottawa and Riviere des Prairies to junction with River St. Lawrence ship channel at Bout de l'Ile.	34·0	55·0	359·0	448·0	

TABLE OF DISTANCES IN STATUTE MILES OF WATER ROUTES.

PROPOSED NEW CANADIAN ROUTE.

Via Great Lakes, Georgian Bay Ship Canal and Montreal.	Distance to Montreal.	Distance Montreal to Liverpool via Belle Ile.	Total Distance.
Fort William to Liverpool	934	3,189	4,123
Duluth "	1,056	3,189	4,245
Milwaukee "	906	3,189	4,095
Chicago "	972	3,189	4,161

PRESENT CANADIAN ROUTE.

Via Great Lakes, Welland and River St. Lawrence Canals and Montreal.	Distance to Montreal.	Distance Montreal to Liverpool via Belle Ile.	Total Distance.
Fort William to Liverpool	1,216	3,189	4,405
Duluth "	1,338	3,189	4,527
Milwaukee "	1,176	3,189	4,365
Chicago "	1,242	3,189	4,431

UNITED STATES ROUTE.

Via Great Lakes, Erie Canal, Hudson River and New York.	Distance to New York.	D stance New York to Liverpool.	Total Distance.
Fort William to Liverpool	1,358	3,571	4,929
Duluth "	1,480	3,571	5,051
Milwaukee "	1,318	3,571	4,889
Chicago "	1,384	3,571	4,955

TABLE OF DISTANCES IN STATUTE MILES OF WATER AND RAILWAY ROUTES.

CANADIAN ROUTES.

	Grand Trunk Railway Route. Depot Harbour–Montreal.				Grand Trunk Railway Route. Midland–Montreal.			
	Distance to Depot Harbour.	Distance Depot Harbour to Montreal.	Distance Montreal to Liverpool via Belle Ile.	Total Distance.	Distance to Midland.	Distance Midland to Montreal.	Distance Montreal to Liverpool. via Belle Ile.	Total Distance.
Fort William to Liverpool....	516	381	3,189	4,086	540	383	3,189	4,112
Duluth to Liverpool.........	638	381	3,189	4,208	662	383	3,189	4,234
Milwaukee to Liverpool....	488	381	3,189	4,058	512	383	3,189	4,084
Chicago to Liverpool.......	554	381	3,189	4,124	578	383	3,189	4,150

UNITED STATES ROUTES.

	New York Central Railway Route. Buffalo–New York.				Erie Railway Route. Buffalo–New York.				Lehigh Valley Railway Route. Buffalo–New York.			
	Distance to Buffalo.	Distance, Buffalo to New York.	Distance, New York to Liverpool.	Total Distance.	Distance to Buffalo.	Distance, Buffalo to New York.	Distance, New York to Liverpool.	Total Distance.	Distance to Buffalo.	Distance, Buffalo to New York.	Distance, New York to Liverpool.	Total Distance.
Fort William to Liverpool..............	863	440	3,571	4,874	863	425	3,571	4,859	863	448	3,571	4,882
Duluth to Liverpool..	985	440	3,571	4,996	985	425	3,571	4,981	985	448	3,571	5,004
Milwaukee to Liverpool..............	823	440	3,571	4,834	823	425	3,571	4,819	823	448	3,571	4,842
Chicago to Liverpool.	889	440	3,571	4,900	889	425	3,571	4,885	889	448	3,571	4,908

	West Shore Railway Route. Buffalo–Weehawken.				Deleware, Lackawanna and Western Railway Route. Buffalo–Hoboken.				Pennsylvania Railway Route. Buffalo–New York.			
	Distance to Buffalo.	Distance, Buffalo to Weehawken.	Distance, Weehawken to Liverpool.	Total Distance.	Distance to Buffalo.	Distance, Buffalo to Hoboken.	Distance, Hoboken to Liverpool.	Total Distance.	Distance to Buffalo.	Distance, Buffalo to New York.	Distance, New York to Liverpool.	Total Distance.
Fort William to Liverpool..............	863	429	3,571	4,863	863	411	3,571	4,845	863	508	3,571	4,942
Duluth to Liverpool..	985	429	3,571	4,985	985	411	3,571	4,967	985	508	3,571	5,064
Milwaukee to Liverpool..............	823	429	3,571	4,823	823	411	3,571	4,805	823	508	3,571	4,902
Chicago to Liverpool.	889	429	3,571	4,889	889	411	3,571	4,871	889	508	3,571	4,968

	West Shore & Boston & Albany Railway Route. Buffalo–Boston.				New York Central & Boston & Albany Railway Route. Buffalo–Boston.			
	Distance to Buffalo.	Distance Buffalo to Boston.	Distance Boston to Liverpool.	Total Distance.	Distance to Buffalo.	Distance Buffalo to Boston.	Distance Boston to Liverpool.	Total Distance.
Fort William to Liverpool....	863	489	3,228	4,580	863	499	3,228	4,590
Duluth to Liverpool.........	985	489	3,228	4,707	985	499	3,228	4,712
Milwaukee to Liverpool....	823	489	3,228	4,540	823	499	3,228	4,550
Chicago to Liverpool......	889	489	3,228	4,606	889	499	3,228	4,616

TIME OF TRANSIT.

This is affected by the length of restricted channels on the route, where speed has to be reduced, and by the number of lockages and consequent delays. A close computation of the speed allowable in the different stretches, with three-quarters of an hour delay for passage at each lock, gives about 70 hours, as time of transit from Georgian Bay to Montreal.

With the advantage of shorter distance between terminal harbours, it is computed that the route will be from 1 to 1½ days faster than any other existing water route, under present conditions, from the head of the Great Lakes to an ocean port, apart from also having an enormous superiority as to carrying capacity. But as compared with a possible improved system of St. Lawrence canals to a depth of 22 feet, assuming that the number of locks would be greatly reduced and some of the channels widened, the benefit in time of transit claimed, would naturally be lessened, the saving in distance being offset, to some extent, by the longer stretches of lake and wide river navigation which exist through the Lake Erie and Lake Ontario route, where higher speeds would be permissible.

TERMINAL HARBOURS.

As the harbour of Montreal forms the eastern terminus of the waterway, no special provision is made in the estimate for increased terminal facilities. By the time the waterway is completed, with the works now under construction and the extensive improvements proposed, the harbour will, no doubt afford sufficient dockage facilities to meet the requirements of the increase in traffic contributed by the new route. As this traffic develops, facilities will be extended naturally as part of the harbour works.

In connection with the front route, the large basins created above the Victoria Jubilee bridge, between Nun's island and the Verdun and St. Gabriel levees along the north shore of the St. Lawrence river, will afford ample room for extensive dock facilities for lake boats.

Should the Rivière des Prairies route, back of Montreal island, be selected, splendid facilities for docks and railway yards would also be available.

The possibility of giving an available depth of 25 feet from the St. Lawrence ship channel to the Recollect lock has been considered, with a view of affording terminal facilities, back of Montreal island, for vessels of a maximum draft of 24 feet. This would allow the extension of Montreal harbour in a very desirable location, when need would be felt for more space, leaving the front or main part of the harbour free for deeper draft ocean vessels.

The additional cost over the estimated 22-feet depth for this part of the waterway would be nearly $2,000,000.

The western entrance to the waterway on the Georgian Bay is formed by French River harbour. As this will be only a transit point to and from terminal harbours already established, no terminal facilities are required other than improvements in certain parts of the entrance, and increased aids to navigation. The cost of these improvements is included in the estimate.

LENGTH OF NAVIGATION SEASON.

The length of the navigation season which will be available on the proposed waterway as compared with the conditions prevailing at initial points of the transportation system from the Great Lakes to the sea is of great importance.

Undoubtedly on the proposed waterway, this will be governed by the opening and closing of navigation on Lake Nipissing, and by the conditions at the Summit and Mattawa river reaches.

The following data will be of some use in making comparisons, and in determining the probable number of days which the canal may be expected to be open for navigation.

OPENING AND CLOSING OF NAVIGATION OF ST. MARY'S FALLS CANALS (1880-1905).

Latitude, North 46° 30′.—Elevation above M.S.L. 601·75.

Year.	Date of Opening.	Date of Closing.	Remarks.
1880	April 28	Nov. 15	
1881	May 7	Dec. 5	Average date of opening of navigation, April 23.
1882	April 21	Dec. 3	
1883	May 2	Dec. 11	
1884	April 23	Dec. 10	
1885	May 6	Dec. 2	
1886	April 25	Dec. 4	
1887	May 1	Dec. 2	Average date of closing, December 9.
1888	May 7	Dec. 4	
1889	April 15	Dec. 4	
1890	April 20	Dec. 3	
1891	April 27	Dec. 7	
1892	April 18	Dec. 6	Average number of days open, 230.
1893	May 1	Dec. 5	
1894	April 17	Dec. 6	
1895	April 25	Dec. 11	
1896	April 21	Dec. 8	
1897	April 21	Dec. 14	
1898	April 11	Dec. 14	
1899	April 26	Dec. 20	
1900	April 19	Dec. 16	
1901	April 20	Dec. 21	
1902	April 1	Dec. 20	
1903	April 2	Dec. 15	
1904	April 30	Dec. 26	
1905	April 10	Dec. 20	

OPENING AND CLOSING OF NAVIGATION OF FRENCH RIVER HARBOUR

Latitude, North 46°.—Elevation above M.S.L. 580.

Year.	Date of Opening.	Date of Closing.	Remarks.
1880	April 28	Nov. 27	
1881	May 5	Dec. 1	
1882	April 13	Dec. 2	
1883	May 4	Dec. 1	
1884	May 5	Dec. 10	Average date of opening of navigation, April 26.
1885	May 8	Dec. 6	
1886	April 24	Dec. 3	
1887	April 29	Dec. 1	
1888	May 12	Dec. 4	
1889	April 21	Dec. 4	
1890	April 18	Dec. 2	
1891	April 18	Nov. 30	
1892	April 16	Dec. 3	Average date of closing, December 3.
1893	April 24	Dec. 2	
1894	April 18	Dec. 2	
1895	April 24	Dec. 2	
1896	April 22	....	Average number of days open, 221.
1897	April 24	....	
1898	April 14	....	
1899	April 25	....	
1900	April 23	....	
1901	April 18	Dec. 7	
1902	April 19	Dec. 14	
1903	May 2	Nov. 26	
1904	May 8	Dec. 4	
1905	May 1	Dec. 4	
1906	April 26	Nov. 29	

AUTHORITY.—From 1880 to 1901, J. W. Fraser, survey of 1901. From 1901 to 1906, taken from records of Northern Navigation Company. Date of closing given above is first formation of ice; this first ice often disappears and the harbour keeps open until late in December.

OPENING AND CLOSING OF NAVIGATION ON LAKE NIPISSING, AT NORTH BAY, ONT.

Latitude. North 56° ·15.—Elevation of lake above M.S.L. 640.

Year.	Date of Opening.	Date of Closing.	Remarks.
1886	April 29	Dec. 7	
1887	April 30	Dec. 6	Average date of opening, April 27.
1888	May 5	Dec. 4	
1889	April 26	Dec. 6	
1890	April 23	Dec. 2	
1891	April 23	Dec. 3	
1892	April 16	Dec. 6	
1893	April 30	Dec. 19	Average date of closing, December 4.
1894	April 26	Dec. 17	
1895	April 29	Dec. 13	
1896	April 27	Dec. 11	Average number of days open, 221.
1897	April 29	Dec. 11	
1898	April 17	Dec. 11	
1899	May 2	Dec. 12	
1900	May 1	Dec. 20	These records are from various sources, and in my opinion, dates given are only approximate. It seems that average for length of navigation season should be reduced by about 10 days, making it 211 days. A representative of one of the largest firms operating on the lake, states that in his experience of 22 years, navigation has always closed before December 1st. The earliest he has seen it closed was November 21st. Therefore, 211 days seems about right.
1901	April 28	Dec. 10	
1902	April 27	Nov. 19	
1903	April 27	Nov. 18	
1904	May 4	Nov. 20	
1905	April 27	Nov. 16	
1906	May 2	Nov. 16	

AUTHORITY.—From 1886 to 1901, from J. W. Fraser, survey of 1901. From 1901 to 1907, from captains of boats and other parties. Date of closing for years 1886 to 1901 probably refer to date when lake was frozen over, and date of closing of navigation should be taken at an average of about 12 days earlier.

OPENING AND CLOSING OF CARILLON AND GRENVILLE CANAL.—LOWER OTTAWA RIVER.

1880	April 24	Nov. 28	
1881	May 2	Nov. 26	
1882	April 26	Nov. 27	
1883	May 1	Nov. 27	
1884	April 28	Nov. 24	Average date of opening, April 29.
1885	May 7	Nov. 30	
1886	May 1	Nov. 30	
1887	May 2	Nov. 30	
1888	May 2	Dec. 2	
1889	April 26	Nov. 30	
1890	April 26	Nov. 29	
1891	April 23	Nov. 28	Average date of closing, November 29.
1892	April 30	Nov. 30	
1893	May 1	Nov. 30	
1894	April 23	Nov. 30	
1895	April 29	Nov. 30	
1896	April 27	Nov. 28	Average number of days open, 214.
1897	April 26	Nov. 30	
1898	April 30	Nov. 26	
1899	May 1	Nov. 30	
1900	May 1	Nov. 30	
1901	April 29	Nov. 30	
1902	April 28	Nov. 30	
1903	April 27	Nov. 30	
1904	May 2	Nov. 30	
1905	May 1	Nov. 30	
1906	April 30	Nov. 30	

OPENING AND CLOSING OF STE. ANNE LOCKS.—LOWER OTTAWA RIVER.

Year.	Date of Opening.	Date of Closing.	Remarks.
1880	April 24	Nov. 24	
1881	April 18	Nov. 20	
1882	April 11	Nov. 30	
1883	April 30	Nov. 26	
1884	April 26	Nov. 24	Average date of opening, April 25.
1885	May 5	Nov. 26	
1886	April 27	Nov. 27	
1887	May 4	Nov. 28	
1888	May 2	Nov. 22	
1889	....	Nov. 29	
1890	April 24	Nov. 25	
1891	April 25	Nov. 26	Average date of closing, November 27.
1892	April 29	Nov. 28	
1893	April 29	Nov. 27	
1894	April 21	Nov. 25	
1895	April 27	Nov. 29	
1896	April 26	Nov. 28	
1897	April 29	Nov. 30	Average number of days open, 216.
1898	April 11	Nov. 29	
1899	April 27	Nov. 26	
1900	April 24	Nov. 28	
1901	April 24	Nov. 26	
1902	April 22	Nov. 30	
1903	April 28	Nov. 30	
1904	April 22	Nov. 30	
1905	April 16	Nov. 30	
1906	April 19	Nov. 30	

OPENING AND CLOSING OF LACHINE CANAL.

1880	April 26	Nov. 27	
1881	May 1	Dec. 1	
1882	April 25	Dec. 1	
1883	May 1	Dec. 1	
1884	May 12	Nov. 30	Average date of opening, April 30.
1885	May 4	Nov. 30	
1886	May 3	Nov. 30	
1887	May 4	Nov. 30	
1888	May 1	Dec. 2	
1889	April 21	Nov. 30	
1890	April 23	Nov. 29	
1891	April 28	Nov. 30	
1892	May 1	Nov. 30	
1893	May 4	Nov. 30	
1894	April 23	Nov. 30	Average date of closing, December 1st.
1895	April 30	Nov. 30	
1896	May 3	Nov. 30	
1897	May 1	Dec. 1	
1898	April 25	Dec. 1	
1899	May 1	Nov. 30	
1900	May 3	Dec. 3	
1901	May 1	Nov. 30	
1902	May 1	Dec. 6	
1903	May 1	Dec. 3	Average number of days open, 215.
1904	May 2	Dec. 1	
1905	May 1	Dec. 2	
1906	April 29	Dec. 4	

TABLE SHOWING THE OPENING AND CLOSING OF NAVIGATION, AND THE FIRST ARRIVAL AND LAST DEPARTURE OF SEA-GOING VESSELS IN THE HARBOUR OF MONTREAL SINCE 1880.

Year.	Opening of Navigation.	Closing of Navigation.	First Arrival from Sea.	Last Departure for Sea.
1880	April 17	Dec. 3	May 2	Nov. 22
1881	" 21	Jan. 2 (82)	April 26	" 23
1882	" 11	Dec. 9	May 6	" 21
1883	" 27	" 16	" 5	" 20
1884	" 22	" 18	" 2	" 20
1885	May 5	" 7	" 8	" 20
1886	April 24	" 4	April 30	" 25
1887	May 1	" 23	May 3	" 28
1888	April 29	" 14	" 4	" 22
1889	" 14	" 29	April 27	" 23
1890	" 14	" 3	" 30	" 24
1891	" 17	" 17	" 27	" 21
1892	" 13	" 23	" 23	" 27
1893	" 24	" 4	May 3	" 23
1894	" 12	" 26	April 27	" 24
1895	" 20	" 5	" 27	" 25
1896	" 22	" 19	" 28	" 23
1897	" 17	" 19	" 30	" 24
1898	Mar. 31	" 12	" 26	" 28
1899	April 24	" 30	" 27	" 29
1900	" 21	" 10	" 26	Dec. 3
1901	" 21	" 10	" 25	Nov. 25
1902	" 3	" 8	" 7	Dec. 4
1903	" 2	" 10	" 26	Nov. 28
1904	" 25	" 9	May 4	" 27
1905	" 19	" 12	" 2	" 30
1906	" 20	" 2	April 28	Dec. 2
1907	" 23	" 15	May 2	" 2

The average date of first arrival from sea in last 21 years is April 24.

The average date of last departure for sea in last 21 years is November 25.

Average number of days open for ocean navigation 215 days.

The removal of the buoys from the ship channel between Montreal and Quebec is usually commenced between November 20 and 24.

Authority, Montreal Harbour Commissioners' Reports.

Summarizing, the length of the navigation season at the ports and other places covered by the records given above is as follows:—

St. Mary's Falls canals	230 days.
French river harbour, western end of canal	221 "
Lake Nipissing and Summit level, approx	211 "
Carillon and Grenville canal, lower Ottawa river	214 "
St. Anne's lock, lower Ottawa river	216 "
Lachine canal, St. Lawrence route	215 "
Montreal harbour, ocean navigation	215 "

In looking over the list giving the dates of opening and closing for Lake Nipissing, it will be noticed that the navigation season was reduced from 221 days resulting from these dates, to 211 days, on account of the imperfect records available, in order to eliminate all possible chance of over-estimation.

The reduced figures, I believe, represent fairly the average length of time the waterway will be open for navigation, every year, and it may be said to be practically the same as for the lower Ottawa river, the Lachine canal and the season of ocean navigation for the harbour of Montreal, which governs the water-borne import and export trade through the St. Lawrence river route.

TIME OF CONSTRUCTION.

A careful analysis of the work to be performed shows that it would take from three to five years to develop all contracts and place the whole route under active construction. Some of the sections where heavy submarine excavation is encountered would require at least five years to complete, under the best conditions of labour and equipment. It may be fairly stated, therefore, that a period of ten years from inception would be necessary to open the waterway to navigation. This would mean an average expenditure of about $10,000,000 per year.

UNIT PRICES.

The prices for concrete, metal work, excavation, etc., used for the estimate of cost, were adopted after a careful investigation of the actual cost of the same kind of work performed for the department or elsewhere under similar conditions, and after studying unit prices used in other estimates for large canal projects.

Locks.—Locks constitute about 30 per cent of the whole cost of the project. The excavation of foundations amounts to about 15 per cent of the cost of the locks. As the excavation is considered to be done in the dry in most cases or within a dam, it is placed at prices for dry work, that is $1 and $1.10 per cubic yard for rock and 25 to 35 cents per cubic yard for loose material, according to conditions of site.

For unwatering, an allowance of $10,000 per lock is made, for building dams, pumping, snow removal, etc. This is an uncertain item, but in many cases it will require very little expenditure to keep the lock pits dry during construction.

Concrete amounts to 40 per cent of the cost of the locks. The price set, $7.50 per cubic yard, is intended to cover all materials required and in all localities. This may seem to be a high price for the large quantities of concrete required, and it may be that bids could be received as low as $6 per cubic yard, but the increasing cost of lumber for forms, difficulties of delivery of cement in some cases, etc., dictate a round allowance per cubic yard.

Piers amount to about 30 per cent of the cost of the locks. Generally they extend 2,000 feet above and below each lock. Timber cribs well filled with excavated rock are used for the part under water, and upon this base, a concrete wall provided with mooring posts and backed with loose rock filling. In some cases, however, the piers have been estimated as entirely built of timber.

The prices as fixed, are for crib work, $3 and $3.50 according to location; for concrete walls $7.50 and for loose rock back filling 50 cents per cubic yard. In view of the large masses of blasted rock which will be available from canal cuttings and lock pits, these prices are considered very liberal.

The quantites of structural steel in gates have been calculated from detailed plans, and 10 per cent added. The price set, 6 cents per pound, or $120 per ton, includes all kinds of steel used.

For the valves, operating machines, storage batteries and lights, the cost has been estimated for a standard lock and applied at each locality. The storage batteries provided at each lock are assumed to be filled either from local plants, already existing in the vicinity, or from small power units specially developed close to the locks, and are sufficient to operate and light for 48 hours.

An allowance of $10,000 for mooring posts, ladders, life lines, etc., is made for each lock.

Dams and Regulations.—Dams and regulating sluice-ways form about 7 per cent of the whole cost of the project.

Although the price fixed for excavation includes the removal and disposal of material, still 50 cents per cubic yard loose is estimated to cover the placing of the rock in dams to the desired lines, and 25 to 35 cents per cubic yard is allowed for an

earth face, although it may not be deemed necessary in all cases. When concrete overflow dams are placed and for all concrete work in connection with regulating works the price per cubic yard is fixed at $7,50. The timber for stop-logs may be obtained locally or from British Columbia, and the prices used for the estimates vary from $30 to $50 per thousand feet B.M.

Excavation in channels, including guide piers and lighting system amounts to 55 per cent of the whole cost of the proposed waterway.

For submarine rock work which requires to be drilled, blasted and removed by dredge, the price has been fixed at $3.00 and $3.50 per cubic yard. Probably this may be fair enough for granite, which forms the large bulk of the excavation, but it will be more than ample for work in limestone, some of which may be dredged without drilling and blasting.

The price of $1.00 and $1.10 per cubic yard for dry work is fair, owing to the large quantities to be excavated and because an additional 50 cents per loose cubic yard is allowed for placing great quantities of the excavated material in dams and embankments.

The dredging of material other than rock is estimated at prices ranging from 20 cents to 35 cents per yard. The first price applies to soft material, or soft clay and sand that can be excavated by hydraulic dredging.

The price of 35 cents applies to hard material, including indurated clay and a mixture of clay, gravel, cobbles and boulders.

Earth excavation in the dry, ranges in price from 25 cents to 35 cents, and in case of cemented material, to $1.00 per cubic yard.

The great part of this material is from canal cuttings, and will be used in embankments for which an allowance is made.

Where banks require to be lined with stone, the price set is $2.00 per cubic yard.

In regard to guide cribs along submerged channels, these are estimated at $3.00 per cubic yard.

An allowance of $250 is made for each light placed on the cribs.

In regard to range lights, the cost of two small lighthouses, with lights and reflectors complete, on each course, is fixed at $2,000.

Damages amount to about 8 per cent of the total cost of the project.

DETAILED ESTIMATES OF COST AND SUMMARIES, WITH ESTIMATE PLANS.

In the following estimates of cost, the quantities have been taken separately for each reach or change of level, each level forming a convenient sub-division for the whole route. A reach generally, for the purpose of the estimate, includes all works and structures governing it, from the lower entrance to a lock, including approaches and dams, to the foot of the lower approaches of the next lock above, excepting for the Summit reach which includes locks at both ends.

The quantities have been determined and checked very closely for the various items.

In each estimate of cost, land and other damages are partly covered by specific items and partly by contingencies. In most cases of undeveloped water powers, it has been assumed that owners could be compensated by being granted power priveleges at nearest dam. Cost of damages, at best, cannot be well defined in this estimate. In ten years from now, it is likely that the damages to pay would be much larger, as conditions on the rivers followed would be much more involved. Therefore the amount of damages to pay when the waterway is completed cannot be well foreseen. It will probably increase with every year of delay in commencing construction. This amount may be larger than estimated by two or three million dollars,

according to conditions at the time of construction and the legal view taken of some of the claims likely to arise.

The cost of each level is subdivided as follows:—

1st.—Lock, guide piers and equipment.

2nd.—Dam and regulating sluices.

3rd.—Channel excavation, guide cribs, range and marking lights.

4th.—Damages to lands, railway tracks, water powers, &c., including also new bridges required.

ESTIMATES OF COST FOR A NAVIGABLE WATERWAY, 22 FEET DEEP, FROM MONTREAL TO GEORGIAN BAY VIA THE OTTAWA, MATTAWA AND FRENCH RIVERS.

SUMMARY OF COST.

Route A.

Via Montreal, Lake St. Louis, Ste. Anne de Bellevue, Ottawa, Rocher Fendu channel, Coulonge, Pembroke, Des Joachims, Mattawa, Talon lake, North Bay, Lake Nipissing and French river.

Locks, dams, channels, piers, lighting, damages	$88,626,108
Contingencies, engineering, administration, &c.	8,862,892
Storage of flood waters, regulation basins, telephones, &c.	2,200,000
Total,	$99,689,000
Feeder at Summit, when required	987.485

Route B.

Same as Route A, excepting that Riviere des Prairies (Back river) one of the branches of the Ottawa river, north of Montreal island, is followed, instead of Lake St. Louis and the St. Lawrence river from Ste. Anne to Montreal as in Route A.

Locks, dams, channels, piers, lighting, damages	$83,354,508
Contingencies, engineering, administration, &c.	8,335,492
Storage of flood waters, regulation basins, telephones, &c.	2,200,000
Total	$93,890,000
Feeder at Summit, when required	987.485

MONTREAL REACH.

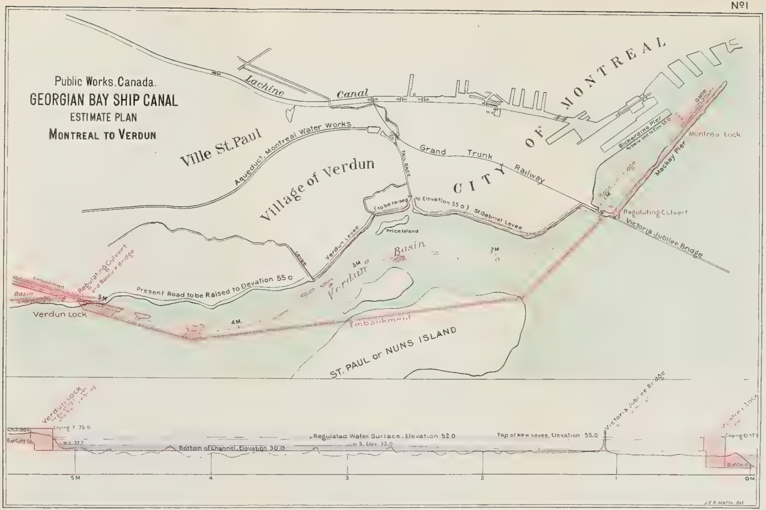
Custom House to Verdun, Miles 0 to 5.

Surface Elevation 52, Surface below Lock Elevation 20, Lift 32 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Montreal Lock—					
Excavation rock, dry	C. yds.	75,474	1 00	75,474	
Unwatering pit				10,000	
Concrete, lock walls, &c	C. yds.	60,100	7 50	450,750	
Entrance piers, cribwork	"	95,100	3 50	332,850	
Entrance piers, concrete wall	"	7,300	7 50	54,750	
Entrance piers, rock fill (back of wall)	"	43,800	0.50	21,900	
Lock gates	Tons.	876	120 00	105,120	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery.	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, &c				10,000	
					1,090,684
Dam and Regulation—					
Dam, rock, loose	C. yds.	94,200	0 50	47,100	
Earth face	"	23,500	0 25	5,900	
Regulating culvert at Mackay pier				10,000	
Operating machines				1,000	
					64,000
Channel—					
Excavation, rock, wet	C. yds.	177,000	3 00	531,000	
Excavation, rock, dry	"	81,600	1 00	81,600	
Embankment, loose rock	"	250,000	0 50	125,000	
Embankment, earth	"	1,800,000	0 25	450,000	
Raising Bickerdike pier				61,250	
Bank lining	C. yds.	48,700	2 00	97,400	
Range lights, marking piers, &c				6,000	
					1,352,250
Damages—					
Land and rights, Nuns and Price islands				47,200	
Water supplies, Montreal City and Waterworks Co.				535,000	
Drainage, Verdun				250,000	
Railway bridges				454,800	
Highway bridges				65,000	
					1,352,000
					3,858,934
Contingencies, engineering, &c					385,893
Total					4,244,827

For analysis and general features, refer to page 92 and estimate plan No. 1.

Nº1


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
MONTREAL TO VERDUN
Lachine Canal
Ville St. Paul
Aqueduct. Montreal Water Works
Village of Verdun
Grand Trunk Railway
CITY OF MONTREAL
Bickerdike Pier
Mackay Pier
Montreal Lock
Regulating Culvert
Victoria Jubilee Bridge
St Gabriel Levee
Price Island
Verdun Basin
Verdun Levee
Regulating Culvert and Bascule Bridge
Embankment
Basin
Verdun Lock
Present Road to be Raised to Elevation 55.0
Embankment
ST. PAUL or NUNS ISLAND
Regulated Water Surface. Elevation 52.0
Bottom of Channel. Elevation 30.0
Top of New Levee. Elevation 55.0
5M
4
3
2
1
0M.
J.E.R. Mollo, Del

LAKE ST. LOUIS REACH.

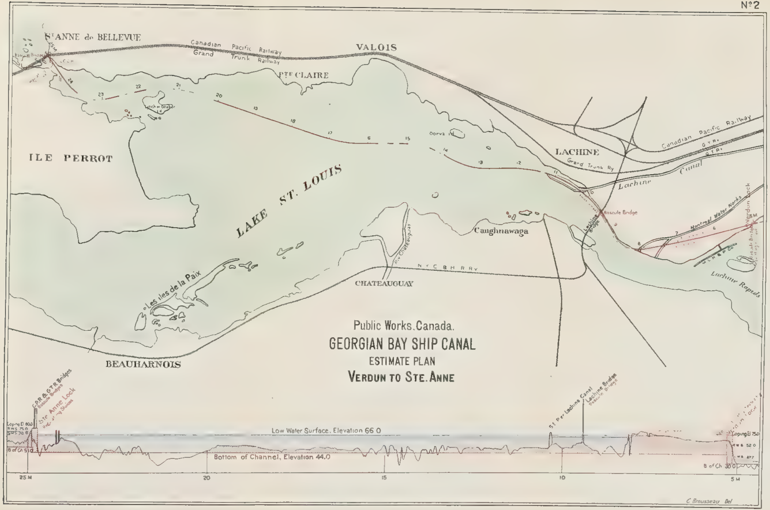
Verdun to St. Anne, Miles 5 to 25.

Surface Elevation 70, Surface below Lock Elevation 52, Lift 18 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Verdun Lock—				
Excavation, rock, dry..........C. yds.	132,000	1 00	132,000	
Excavation, earth, dry.......... "	24,726	0 25	6,200	
Unwatering pit..........	....	....	10,000	
Concrete, lock walls, etc..........C. yds.	54,000	7 50	405,000	
Entrance piers, cribwork.......... "	93,228	3 50	326,300	
Entrance piers, concrete wall.......... "	3,400	7 50	63,000	
Entrance piers, rock fill (back of wall)..... "	50,400	0 50	25,200	
Lock gates.......... Tons.	712	120 00	85,440	
Gate operating machines.......... Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights...	....	....	10,000	
Bollards, ladders, life chains, &c..........	....	....	10,000	
				1,092,980
Dam and Regulation—				
Regulating culvert at lock..........	....	....	7,760	
Operating machines..........	....	....	4,440	
				12,200
Channel—				
Excavation, rock, wet..........C. yds.	2,203,268	3 00	6,609,804	
Excavation, rock, dry.......... "	2,305,872	1 00	2,305,872	
Excavation, earth, wet.......... "	1,977,530	0 30	593,300	
Excavation, earth, dry.......... "	3,053,667	0 25	763,417	
Embankment, loose rock.......... "	928,436	0 50	464,218	
Embankment, earth.......... "	532,710	0 15	80,378	
Cribwork.......... "	29,593	3 50	103,576	
Concrete walls.......... "	2,000	7 50	15,000	
Rock fill back of walls.......... "	12,000	0 50	6,000	
Bank lining.......... "	42,100	2 00	84,200	
Range lights, marking piers, &c..........	....	....	45,000	
				11,070,765
Damages—				
Land and rights..........	....	....	240,000	
Water supplies, Lachine waterworks..........	....	....	7,000	
Railway bridges..........	....	....	120,000	
Highway bridges..........	....	....	10,000	
				377,000
				12,552,945
Contingencies, engineering, &c..........	....	....	....	1,255,294
Total..........	....	....	....	13,808,239

For analysis and general features, refer to page 94 and estimate plan No. 2.

Nº2



STE ANNE de BELLEVUE
Canadian Pacific Railway
Grand Trunk Railway
VALOIS
PTE CLAIRE
ILE PERROT
LAKE ST. LOUIS
Dorval Id
LACHINE
Grand Trunk Ry
Canadian Pacific Railway
Lachine Canal
Bascule Bridge
Lachine Bridge
Montreal Water Works
Verdun Lock
Caughnawaga
Lachine Rapids
Riv Chateauguay
N Y C & H R RY
CHATEAUGUAY
Les Iles de la Paix
BEAUHARNOIS
Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
VERDUN TO STE. ANNE
C.P.R. & G.T.R. Bridges
Bascule Bridges
Ste Anne Lock
Regulating Sluices
St Per Lachine Canal
Lachine Bridge
Bascule Bridge
Low Water Surface. Elevation 66.0
Bottom of Channel. Elevation 44.0
Coping El 75.0
B of Ch 30.0
25 M
20
15
10
5 M
C. Brousseau Del

OKA LAKE REACH.—(Lake of Two Mountains.)

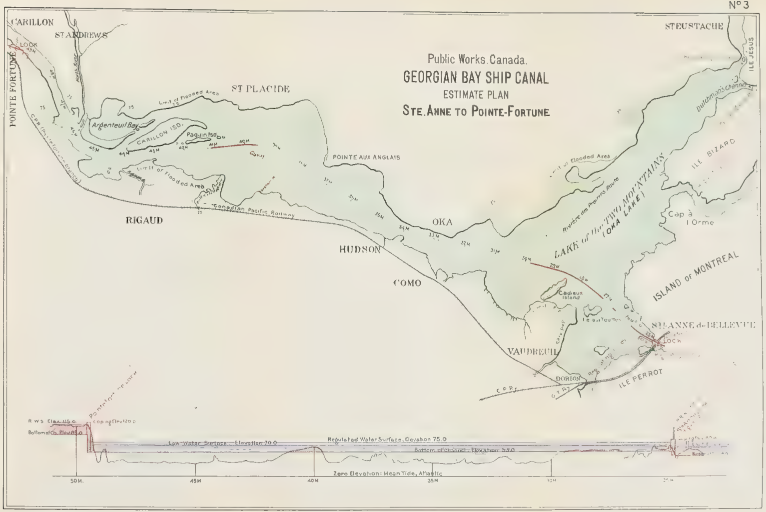
St. Anne to Pointe Fortune, Miles 25 to 49.

Surface Elevation 75, Surface below Lock, Elevation 70, Lift 5 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
St. Anne Lock—					
Excavation, rock, dry	C. yds.	41,800	1 00	41,800	
Unwatering pit				10,000	
Concrete, lock walls, &c	C. yds.	35,500	7 50	266,250	
Entrance piers, cribwork	"	82,499	3 50	288,747	
Entrance piers, concrete wall	"	6,600	7 50	49,500	
Entrance piers, rock fill (back of wall)	"	39,600	0 50	19,800	
Lock gates	Tons.	574	120 00	68,880	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, &c				10,000	
					784,817
Dam and Regulation—					
Dam, rock, loose	C. yds.	45,800	0 50	22,900	
Dam, earth, face	"	11,500	0 50	5,750	
Dam, borrow pit, rock	"	23,000	1 00	23,000	
Stop-log sluices				302,100	
Operating machines	Each.	10	700 00	7,000	
					360,750
Channel—					
Excavation, rock, wet	C. yds.	192,100	3 00	576,300	
Excavation, earth, wet	"	1,675,879	0 20	335,176	
Range lights, marking piers, &c				25,850	
					937,326
Damages—					
Land and rights				188,475	
Railway bridges				62,600	
					251,075
					2,333,968
Contingencies, engineering, &c					233,397
Total					2,567,365

For analysis and general features, refer to page 98 and estimate plan No. 3.

Nº 3



Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
STE. ANNE TO POINTE-FORTUNE
CARILLON
ST ANDREWS
POINTE FORTUNE
LOCK
ST PLACIDE
Limit of Flooded Area
Argenteuil Bay
CARILLON ISD.
Paquin Isd.
POINTE AUX ANGLAIS
Canadian Pacific Railway
RIGAUD
HUDSON
COMO
OKA
LAKE of the TWO MOUNTAINS
(OKA LAKE)
Rivière des Prairies Route
STEUSTACHE
ILE JESUS
Dutchman's Channel
ILE BIZARD
Cap à l Orme
ISLAND of MONTREAL
Cadieux Island
STE ANNE de BELLEVUE
LOCK
VAUDREUIL
DORION
ILE PERROT
C.P.R.
G.T.R.
R.W.S. Elev. 115.0
Bottom of Ch. Elev. 93.0
Low Water Surface - Elevation 70.0
Regulated Water Surface, Elevation 75.0
Bottom of Channel - Elevation 53.0
Zero Elevation: Mean Tide, Atlantic
50M.
45M
40M
35M

POINTE FORTUNE REACH.

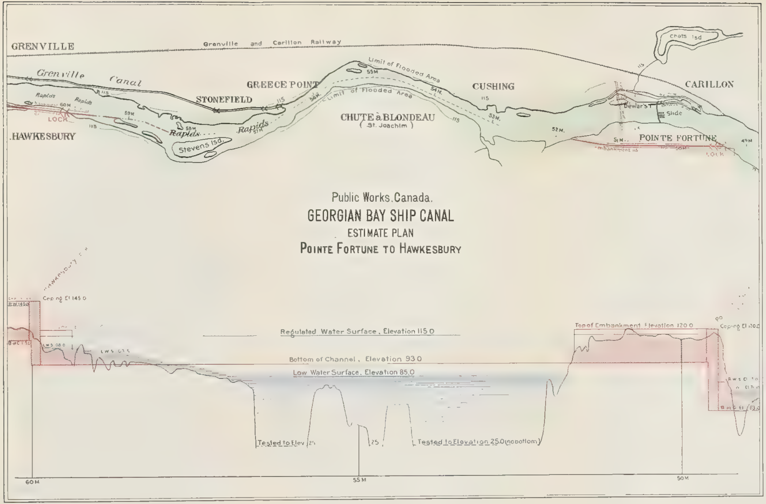
Pointe Fortune to Hawkesbury, Miles 49 to 60.

Surface Elevation 115, Surface below Lock Elevation 75, Lift 40 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Pointe Fortune Lock—					
Excavation, rock, dry	C. yds.	156,775	1 00	156,775	
Excavation, earth, dry	"	177,009	0 35	61,953	
Unwatering pit				10,000	
Concrete, lock walls, &c	"	84,582	7 50	634,365	
Entrance piers, cribwork	"	101,957	3 50	356,850	
Entrance piers, concrete wall	"	9,700	7 50	72,750	
Entrance piers, rock fill (back of wall)	"	58,200	0 50	29,100	
Lock gates	Tons.	965	120 00	115,800	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery.	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, &c				10,000	
					1,477,433
Dam and Regulation—					
Dam, rock, loose	C. yds.	390,090	0 50	195,000	
Dam, earth, face	"	97,522	0 25	24,400	
Stop-log sluices				140,380	
Operating machines	Each.	3	700 00	2,100	
					361,880
Channel—					
Excavation, rock, wet	C. yds.	342,048	3 00	1,026,200	
Excavation, rock, dry	"	356,915	1 00	356,915	
Excavation, earth, dry	"	1,165,090	0 35	407,800	
Bank lining	"	23,500	2 00	47,000	
Range lights, marking piers, &c				43,000	
					1,880,915
Damages—					
Land and rights				128,595	
Highway diversion				2,000	
Highway bridges				10,000	
					140,595
					3,860,823
Contingencies, engineering, &c					386,082
Total					4,246,905

For analysis and general features, refer to page 103 and estimate plan No. 4.

No 4


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
Pointe Fortune to Hawkesbury
GRENVILLE
Grenville and Carillon Railway
Grenville Canal
GREECE POINT
STONEFIELD
CUSHING
CARILLON
Chats Isd
Limit of Flooded Area
CHUTE à BLONDEAU
(St. Joachim)
HAWKESBURY
Stevens Isd.
Rapids
LOCK
Dewar's
Slide
POINTE FORTUNE
Regulated Water Surface, Elevation 115.0
Bottom of Channel, Elevation 93.0
Low Water Surface, Elevation 85.0
Top of Embankment Elevation 120.0
Tested to Elevation 25.0 (no bottom)
60 M
55 M
50 M

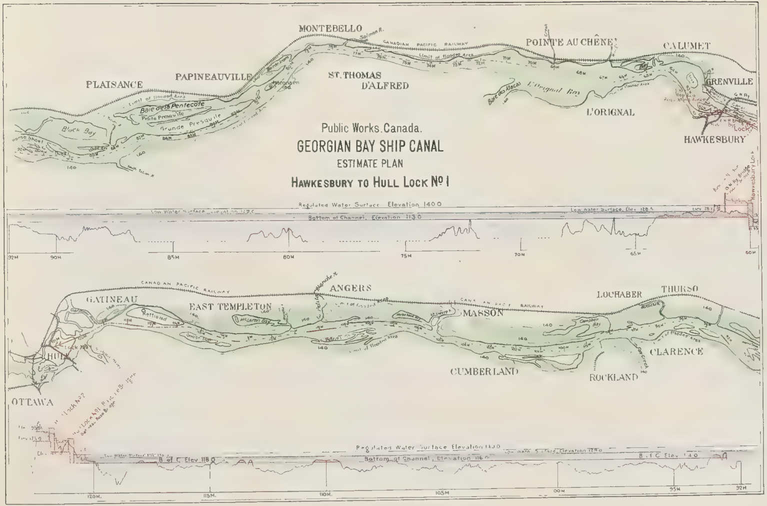
OTTAWA REACH.

Hawkesbury to Hull, Miles 60 to 121.

Surface Elevation 140, Surface below Lock, Elevation 115, Lift 25 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Hawkesbury Lock—				
Excavation, rock, dry........................C. yds.	115,750	1 00	115,750	
Excavation, earth, dry.................... "	9,430	0 35	3,300	
Unwatering pit..................................	....	....	10,000	
Concrete, lock walls, &c...................C. yds.	62,200	7 50	466,500	
Entrance piers, cribwork .... "	49,629	3 50	173,700	
Entrance piers, concrete wall............. "	8,000	7 50	60,000	
Entrance piers, rock fill (back of wall)...... "	48,000	0 50	24,000	
Lock gates................................ Tons.	804	120 00	96,480	
Gate operating machines.................. Each.	8	500 00	4,000	
Filling and emptying valves and machinery "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights..	....	....	10,000	
Bollards, ladders, life chains, &c................	....	....	10,000	
				989,570
Dam and Regulation—				
Dam, rock, loose..........................C. yds.	9,440	0 50	4,720	
Dam, earth, face.......................... "	2,360	0 50	1,180	
Dam borrow pit, rock..................... "	4,720	1 00	4,720	
Stop-log sluices................................	....	....	193,726	
Operating machines...................... Each.	5	700 00	3,500	
				207,846
Channel—				
Excavation, rock, wet....................C. yds.	703,553	3 00	2,110,659	
Excavation, rock, dry.................... "	703,734	1 00	703,734	
Excavation, earth, wet.................... "	1,400,248	0 20	280,050	
Excavation, earth, dry.................... "	167,777	0 35	58,722	
Embankment, loose rock.................. "	308,100	0 50	154,050	
Embankment, earth....................... "	195,781	0 25	48,945	
Cribwork..................................... "	60,929	3 50	213,250	
Concrete walls............................. "	7,400	7 50	55,500	
Rock fill back of walls.................... "	44,400	0 50	22,200	
Range lights, marking piers, &c..............	....	....	103,800	
				3,750,910
Damages—				
Land and rights..................................	....	....	1,062,325	
Water supplies..................................	....	....	5,000	
Drainage..	....	....	5,000	
Railway diversion...............................	....	....	25,000	
Railway bridges.................................	....	....	123,212	
Highway bridges................................	....	....	1,000	
				1,221,537
				6,169,863
Contingencies, engineering, &c..................	....	....	....	616,986
Total..	....	....	....	6,786,849

For analysis and general features, refer to page 104 and estimate plan No. 5.


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
HAWKESBURY TO HULL LOCK Nº I
MONTEBELLO
POINTE AU CHÊNE
CALUMET
GRENVILLE
PLAISANCE
PAPINEAUVILLE
ST. THOMAS
D'ALFRED
L'ORIGNAL
HAWKESBURY
Canadian Pacific Railway
Baie de la Pentecote
Petite Presquile
Grande Presquile
Black Bay
L'Orignal Bay
Regulated Water Surface Elevation 140.0
Bottom of Channel Elevation 113.0
GATINEAU
EAST TEMPLETON
ANGERS
MASSON
LOCHABER
THURSO
CLARENCE
CUMBERLAND
ROCKLAND
HULL
OTTAWA
Regulated Water Surface Elevation 140.0
Bottom of Channel Elevation 116.0

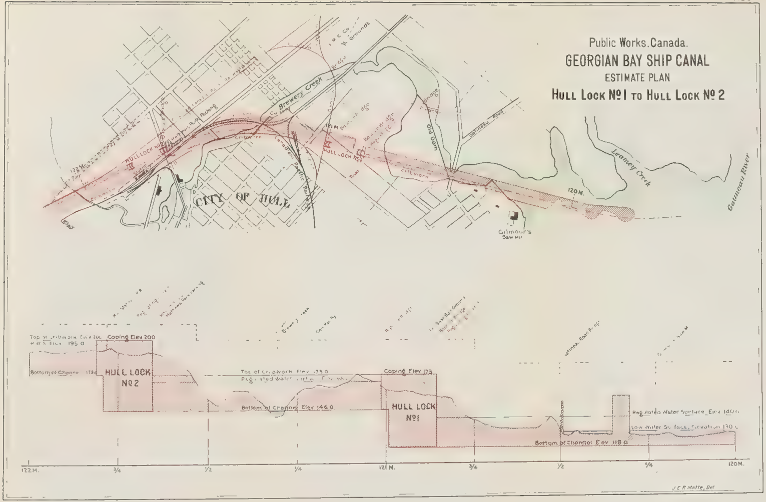
HULL REACH.

Hull Lock No. 1 to Hull Lock No. 2, Miles 121 to 122.

Surface Elevation 168, Surface below Lock, Elevation 140, Lift 28 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$ cts.	$ cts
Hull Lock No. 1—					
Excavation, rock, dry	C. yds.	218,476	1 00	218,476	
Excavation, earth, dry	"	291,712	0 35	102,100	
Unwatering pit				10,000	
Concrete, lock walls, etc	C. yds.	54,750	7 50	410,625	
Entrance piers, cribwork	"	6,746	3 50	23,610	
Entrance piers, concrete wall	"	4,000	7 50	30,000	
Lock gates	Tons.	792	120,000	95,040	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, etc				10,000	
					929,691
Dam and Regulation—					
Stop-log sluices				5,000	
Operating machines	Each.	1	700 00	700	
					5,700
Channel—					
Excavation, rock, dry	C. yds.	365,892	1 00	365,892	
Excavation, earth, dry	"	269,980	0 35	94,493	
Concrete walls	"	36,000	7 50	270,000	
					730,385
Damage—					
Land and rights				500,400	
Drainage				17,600	
Railway diversion				100,000	
Highway diversion				5,000	
Railway bridges				25,000	
Highway bridges				10,000	
					658,000
					2,323,776
Engineering, contingencies, etc					232,377
Total					2,556,153

For analysis and general features refer to page 107 and estimate plan No. 6


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
Hull Lock Nº1 to Hull Lock Nº2
Brewery Creek
CITY OF HULL
HULL LOCK Nº2
HULL LOCK Nº1
Old Dam
Gatineau Road
Leamey Creek
Gatineau River
121 M.
120 M.
Cribwork
Gilmour's Saw Mill
Coping Elev 200
H.W.S. Elev. 195.0
Bottom of Channel 173.0
HULL LOCK Nº2
Top of Cribwork Elev. 173.0
Bottom of Channel Elev 146.0
Coping Elev 173
HULL LOCK Nº1
Regulated Water Surface Elev 140.0
Low Water Surface, Elevation 130.0
Bottom of Channel Elev 118.0
122 M.
3/4
1/2
1/4
121 M.
3/4
1/2
1/4
120 M.
J E R Matte, Del

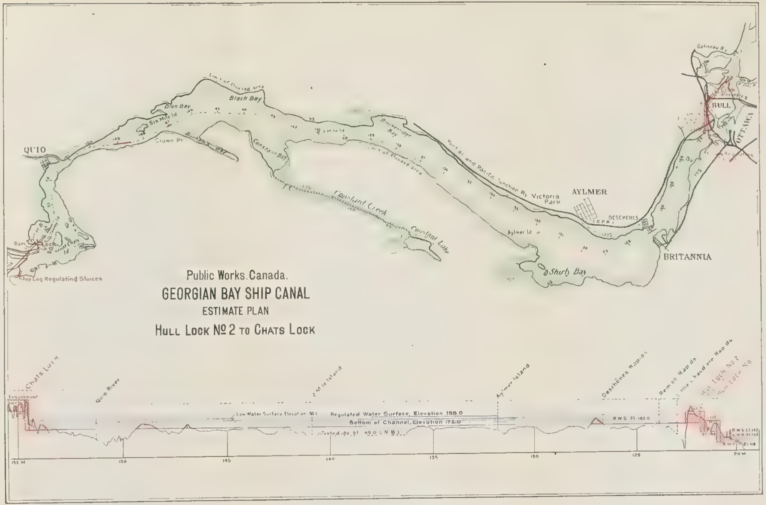
AYLMER REACH.

Hull to Chats Rapids, Miles 122 to 154.

Surface Elevation 195, Surface below Lock, Elevation 168, Lift 27 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$ cts.	$ cts.
Hull Lock No. 2—				
Excavation, rock, dry.....C. yds.	143,500	1 00	143,500	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, etc..... "	37,490	7 50	281,200	
Entrance piers, cribwork..... "	17,349	3 50	60,720	
Entrance piers, concrete wall..... "	6,000	7 50	45,000	
Lock gates.....Tons.	779	120 00	93,480	
Gate operating machines.....Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights..	.....	.....	10,000	
Bollards, ladders, life chains, etc.....	.....	.....	10,000	
				673,740
Dam and Regulation—				
Dam rock, loose.....C. yds.	555,765	0 50	277,900	
Dam earth, face..... "	138,941	0 25	34,700	
Stop-log sluices and regulating culvert.....	.....	.....	86,730	
Operating machines.....Each.	6	.....	7,240	
				406,570
Channel—				
Excavation, rock, wet.....C. yds.	733,818	3 00	2,201,500	
Excavation, rock, dry..... "	587,904	1 00	587,900	
Excavation, earth, wet..... "	512,434	0 20	102,500	
Range lights, marking piers, etc.....	.....	.....	46,900	
				2,938,800
Damages—				
Land and rights.....	.....	.....	493,020	
Water supplies.....	.....	.....	25,000	
Water powers.....	.....	.....	875,000	
Railway diversion.....	.....	.....	170,000	
Highway diversion.....	.....	.....	7,000	
Highway bridge.....	.....	.....	10,000	
				1,580,020
				5,599,130
Contingencies, engineering, etc.....	.....	.....	.....	559,913
Total.....	.....	.....	.....	6,159,043

For analysis and general features refer to page 108 and estimate plan No. 7.


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
Hull Lock No 2 to Chats Lock
QUIO
HULL
OTTAWA
AYLMER
DESCHENES
BRITANNIA
Victoria Park
Black Bay
Dion Bay
Six Mile Id
Crown Pt
Constant Bay
Constant Creek
Constant Lake
Aylmer Id
Gatineau R.
Stop Log Regulating Sluices
Chats Lock
Quio River
Aylmer Island
Deschênes Rapids
Embankment
Regulated Water Surface, Elevation 198.0
Bottom of Channel, Elevation 178.0
R.W.S. El. 180.0
155 M
150
145
140
135
130
125
120 M

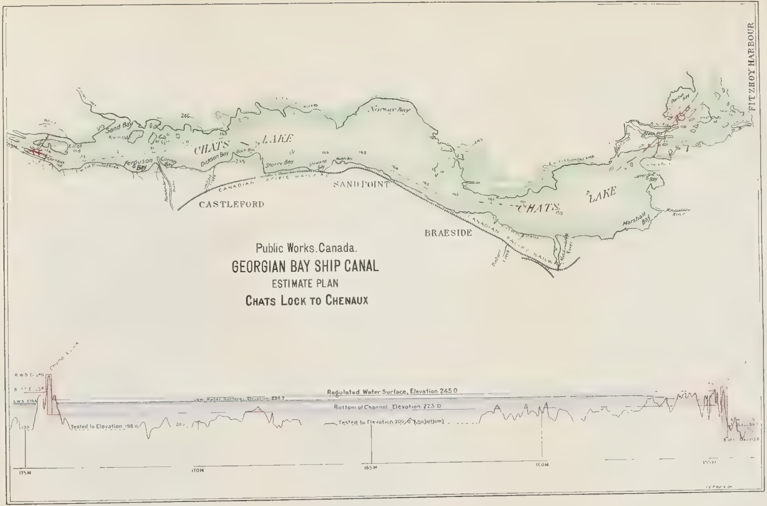
ARNPRIOR REACH.

Chats Rapids to Chenaux Rapids, Miles 154 to 174.

Surface Elevation 245, Surface below Lock, Elevation 195, Lift 50 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$ cts.	$ cts.
Chats Lock—				
Excavation, rock, dry.......C. yds.	221,866	1 00	221,900	
Unwatering pit..........	....	....	10,000	
Concrete, lock walls, etc.......C. yds.	38,850	7 50	291,400	
Entrance piers, cribwork....... "	9,543	3 50	33,400	
Entrance piers, concrete wall....... "	8,200	7 50	61,500	
Entrance piers, rock fill (back of wall)..... "	49,200	0 50	24,600	
Lock gates.......Tons.	1,130	120 00	135,600	
Gate operating machines.......Each.	8	500 00	4,000	
Filling and emptying valves and machinery "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights..	....	....	10,000	
Bollards, ladders, life chains, etc.......	....	....	10,000	
				818,240
Dam and Regulation—				
Dam rock, loose.......C. yds.	613,277	0 50	306,640	
Dam earth, face....... "	185,954	0 50	92,980	
Stop-log sluices.......	....	....	76,000	
Operating machines.......Each.	3	700 00	2,100	
				477,720
Channel—				
Excavation, rock, wet.......C. yds.	256,260	3 00	768,800	
Excavation, rock, dry....... "	562,904	1 00	562,904	
Excavation earth, wet....... "	24,861	0 35	8,700	
Embankment, loose rock under cribwork..... "	39,397	0 50	19,700	
Range lights, marking piers, etc....... "	....	....	61,300	
				1,421,404
Damages—				
Land and rights.......	....	....	28,335	
				28,335
				2,745,699
Contingencies, engineering, etc.......	....	....	....	274,569
Total.......	....	....	....	3,020,268

For analysis and general features refer to page 111 and estimate plan No. 8.


FITZROY HARBOUR
CHATS LAKE
CHATS LAKE
Sand Bay
Ferguson Bay
Dickson Bay
Storry Bay
Norway Bay
Marshall Bay
CANADIAN PACIFIC RAILWAY
CASTLEFORD
SAND POINT
BRAESIDE
Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
CHATS LOCK TO CHENAUX
Regulated Water Surface, Elevation 245.0
Low Water Surface, Elevation 230.7
Bottom of Channel Elevation 223.0
Tested to Elevation 198.0
Tested to Elevation 200.0 (no bottom)
175M
170M
165M
160M

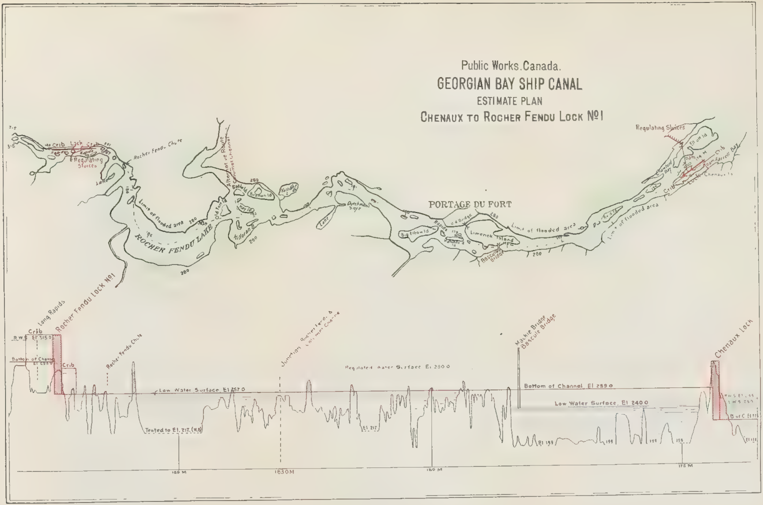
PORTAGE DU FORT REACH.

Chenaux Rapids to Rocher Fendu, Miles 174 to 187.

Surface Elevation 280, Surface below Lock, Elevation 245, Lift 35 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$ cts.	$ cts.
Chenaux Lock—					
Excavation, rock, dry	C. yds.	174,055	1 00	174,100	
Unwatering pit				10,000	
Concrete, lock walls, etc	C. yds.	37,900	7 50	284,250	
Entrance piers, cribwork	"	60,791	3 50	212,770	
Entrance piers, concrete wall	"	7,000	7 50	52,500	
Entrance piers, rock fill	"	78,260	0 50	39,130	
Lock gates	Tons.	890	120 00	106,800	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery.	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, etc				10,000	
					919,390
Dam and Regulation—					
Dam, rock, loose	C. yds.	553,586	0 50	276,793	
Dam, earth, face	"	138,396	0 50	69,198	
Dam, borrow pit rock	"	125,000	1 00	125,000	
Stop-log sluices				123,100	
Operating machines	Each.	3	700 00	2,100	
					596,191
Channel—					
Excavation, rock, dry	C. yds.	336,251	1 00	336,251	
Range lights, marking piers, etc				47,650	
					383,901
Damages—					
Land and rights				52,805	
Water power				10,000	
Highway diversion and raising bridge				5,000	
Highway bridge				65,000	
					132,805
					2,032,287
Contingencies, engineering, etc					203,229
Total					2,235,516

For analysis and general features refer to page 112 and estimate plan No. 9.



Public Works.Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
CHENAUX TO ROCHER FENDU LOCK Nº1
PORTAGE DU FORT
ROCHER FENDU LAKE
Rocher Fendu Chute
Regulating Sluices
Limit of flooded area
Limerick Island
Bascule Bridge
Big Elbow Id
Dutchman's Snye
Regulating Sluices
Long Rapids
Rocher Fendu Lock Nº1
Crib
Rocher Fendu Chute
Regulated Water Surface El 280.0
Low Water Surface El 257.0
Bottom of Channel El 259.0
Low Water Surface El 240.0
Mackie Bridge Bascule Bridge
Chenaux Lock
Tested to El. 217. (N.B.)
183.0 M
175 M

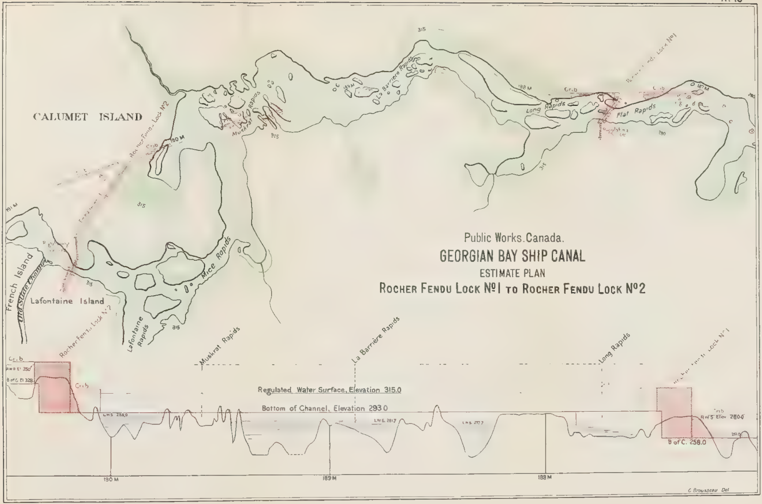
ROCHER FENDU REACH.

Rocher Fendu Lock 1 to Lock 2, Miles 187 to 190.

Surface Elevation 315, Surface below Lock, Elevation 280, Lift 35 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$ cts.	$ cts.
Rocher Fendu Lock No. 1—					
Excavation, rock, dry	C. yds.	81,231	1 00	81,231	
Unwatering pit		....	....	10,000	
Concrete, lock walls, etc	C. yds.	67,337	7 50	505,028	
Entrance piers, cribwork	"	56,772	3 50	198,700	
Entrance piers, concrete wall	"	7,600	7 50	57,000	
Entrance piers, rock fill	"	146,400	0 50	73,200	
Lock gates	Tons.	890	120 00	106,800	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights		....	....	10,000	
Bollards, ladders, life chains, etc		....	....	10,000	
					1,071,799
Dam and Regulation—					
Dam rock, loose	C. yds.	258,734	0 50	129,400	
Dam earth, face	"	64,683	0 50	32,300	
Dam borrow, pit rock	"	133,000	1 00	133,000	
Stop-log sluices		....	....	56,280	
Operating machines	Each.	2	700 00	1,400	
					352,380
Channel—					
Excavation, rock, dry	C. yds.	38,943	1 00	38,943	
Range lights, marking piers, &c		....	....	10,500	
					49,443
Damages—					
Land and rights		....	....	8,220	
					8,220
					1,481,842
Contingencies, engineering, &c		....	....	....	148,184
Total		....	....	....	1,630,026

For analysis and general features refer to page 113 and estimate plan No. 10


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
ROCHER FENDU LOCK Nº1 TO ROCHER FENDU LOCK Nº2
CALUMET ISLAND
French Island
Lafontaine Island
Old Slide Channel
Lafontaine Rapids
Mice Rapids
Muskrat Rapids
La Barrière Rapids
Long Rapids
Flat Rapids
Regulated Water Surface, Elevation 315.0
Bottom of Channel, Elevation 293.0
B of C. 258.0
190 M
189 M
188 M
C. Brousseau Del

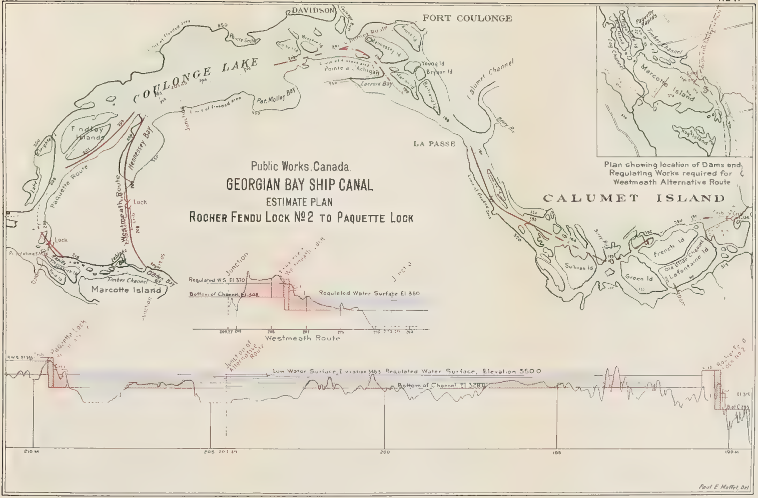
COULONGE LAKE REACH.

Rocher Fendu Lock 2 to Paquette Rapids, Miles 190 to 209.

Surface Elevation 350, Surface below Lock, Elevation 315, Lift 35 feet.

Description.	Quantity.	Price.	Cost.	Totals.
Rocher Fendu Lock No. 2—		$ cts.	$	$
Excavation, rock, dry.....C. yds.	137,852	1 00	137,852	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, &c..... "	41,743	7 50	313,073	
Entrance piers, cribwork..... "	93,114	3 50	325,900	
Entrance piers, concrete wall..... "	7,600	7 50	57,000	
Entrance piers, rock fill..... "	123,600	0 50	61,800	
Lock gates.....Tons.	890	120 00	106,800	
Gate operating machines.....Each.	8	500 00	4,000	
Filling and emptying valves and machinery.....	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights..	.....	.....	10,000	
Bollards, ladders, life chains, &c.....	.....	.....	10,000	
				1,052,265
Dam and Regulation—				
Dam rock, loose.....C. yds.	489,504	0 50	244,752	
Dam earth, face..... "	122,326	0 50	61,163	
Dam borrow, pit rock..... "	142,100	1 00	142,100	
Stop-log sluices.....	.....	.....	137,009	
Operating machines.....Each.	5	700 00	3,500	
				588,524
Channel—				
Excavation, rock, wet.....C. yds.	273,294	3 00	819,882	
Excavation, rock, dry..... "	792,485	1 00	792,485	
Excavation, earth, wet..... "	2,686,190	20 and 35	642,383	
Range lights, marking piers, &c.....	.....	.....	40,150	
				2,294,900
Damages—				
Land and rights.....	.....	.....	4,730	
				4,730
				3,940,419
Contingencies, engineering, &c.....	.....	.....	.....	394,042
Total.....	.....	.....	.....	4,334,461

For analysis and general features refer to page 114 and estimate plan No. 11.



Public Works, Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
Rocher Fendu Lock Nº 2 to Paquette Lock
COULONGE LAKE
DAVIDSON
FORT COULONGE
CALUMET ISLAND
LA PASSE
Calumet Channel
Pointe Sèche
Pointe à l'Achigan
Lacroix Bay
Pat. Molloy Bay
Hennessey Bay
Findley Islands
Paquette Route
Westmeath Route
Marcotte Island
Timber Channel
Young Id
Bryson Id
Sullivan Id
French Id
Green Id
Lafontaine Id
Old Slide Channel
Lock
Junction
Plan showing location of Dams and Regulating Works required for Westmeath Alternative Route
Regulated W.S. El 370
Bottom of Channel El 348
Regulated Water Surface El 350
Westmeath Route
Low Water Surface, Elevation 345.3
Regulated Water Surface, Elevation 350.0
Bottom of Channel El 328.0
Junction of Alternative Route
Paquette Lock
Rocher Fendu Lock Nº 2
210 M
205
200
195
190 M
Paul E. Moffet, Del.

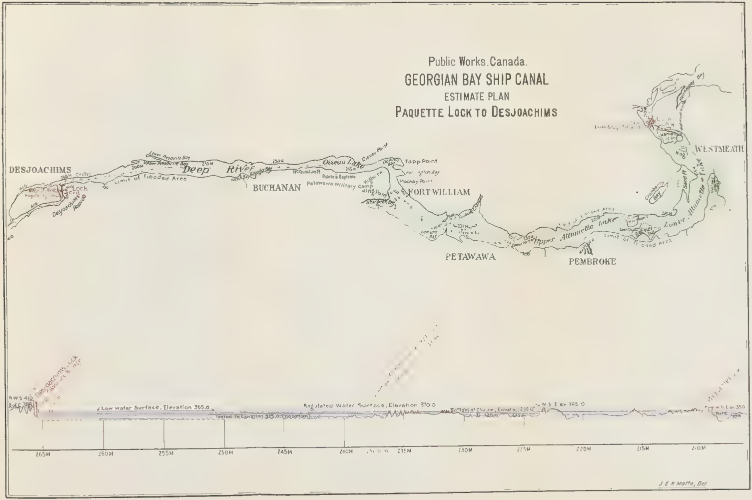
PEMBROKE REACH.

Paquette Rapids to Des Joachims, Miles 209 to 265.

Surface Elevation 370, Surface below Lock, Elevation 350, Lift 20 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Paquette Lock—				
Excavation, rock, dry.....C. yds.	282,531	1 00	282,531	
Excavation, earth, dry..... "	175,848	0 35	61,547	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, &c.....C. yds.	41,528	7 50	311,460	
Entrance piers, cribwork..... "	41,543	3 50	145,400	
Entrance piers, concrete wall..... "	9,200	7 50	69,000	
Entrance piers, rock fill (back of wall).... "	55,200	0 50	27,600	
Lock gates.....Tons.	695	120 00	83,400	
Gate operating machines.....Each .	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights..	.....	.....	10,000	
Bollards, ladders, life chains, &c.....	.....	.....	10,000	
				1,030,778
Dam and Regulation—				
Dam rock, loose.....C. yds.	254,137	0 50	127,069	
Dam earth, face..... "	63,534	0 25	15,883	
Stop-log sluices.....	.....	.....	64,497	
Operating machines.....Each.	3	700 00	2,100	
				209,549
Channel—				
Excavation, rock, wet.....C. yds	1,293,555	1 50	1,940,332	
Excavation, rock, wet..... "	237,000	3 00	711,000	
Excavation, rock, dry..... "	127,236	1 00	127,236	
Excavation, earth, wet..... "	133,333	0 35	46,667	
Excavation, earth, dry..... "	209,696	0 35	73,393	
Range lights, marking piers, &c.....	.....	.....	85,850	
				2,984,478
Damages—				
Land and rights.....	.....	.....	175,285	
				175,285
				4,400,090
Contingencies, engineering, &c.....	.....	.....	.....	440,009
Total.....	.....	.....	.....	4,840,099

For analysis and general features refer to page 115 and estimate plan No. 12.


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
PAQUETTE LOCK TO DESJOACHIMS
DESJOACHIMS
BUCHANAN
FORT WILLIAM
PETAWAWA
PEMBROKE
WESTMEATH
Deep River
Oiseau Lake
Upper Allumette Lake
Lower Allumette Lake
Desjoachims Rapids
Lock
Limit of flooded Area
Lower Presqu'ile Bay
Upper Presqu'ile Bay
Oiseau Point
Tapp Point
Mackay Point
Pointe à Baptême
Petawawa Military Camp
McQuestion Pt
King Point
Sturgeon Bay
Cranberry Bay
Sand Pt
Low Water Surface, Elevation 365.0
Regulated Water Surface, Elevation 370.0
Tested to Elevation 335.0 (no bottom)
265M
260M
255M
250M
245M
240M
235M
230M
225M
220M
215M
210M
J E R Matte, Del

DES JOACHIMS REACH.

Des Joachims to Rocher Captaine, Miles 265·4 to 283·6.

Surface Elevation 410, Surface below Lock, Elevation 370, Lift 40 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Des Joachims Lock—				
Excavation, rock, dry.... C. yds.	228,220	1 00	228,220	
Concrete.... "	68,889	7 50	516,668	
Underwatering....	....	....	10,000	
Equipment—				
Electric light....	....	2,500 00		
Motors and battery....	....	7,500 00		
Valves....	....	15,840 00		
Machinery (for gates) 8 machines....	....	4,000 00	29,840	
Lock gates.... Lbs.	1,930,000	0 06	115,800	
Approaches—				
Cribwork (entrance pier).... C. yds.	123,409	3 50	431,932	
Mooring posts and ladders....	....	....	10,000	
Loose rock beneath and rear of crib.... C. yds.	153,326	0 50	76,663	
				1,419,123
Dams and Regulation—				
Embankment, loose rock south of lock, Ferris Bay, and regulation.... C. yds.	45,255	0 50	22,628	
Embankment, earth.... "	12,031	0 50	6,015	
Sluices (17 stop log sluices)....	....	....	57,852	
Operating machinery (2 at $700)....	....	....	1,400	
				87,895
Channel—				
Excavation, canal prism, rock, dry.... C. yds.	166,586	1 00	166,586	
Excavation, canal prism, rock, wet.... "	273,663	3 50	957,820	
Lighting—				
Lights and marks (from Des Joachims to Ferris Point)....	....	....	19,000	
Light-houses (from Ferris Point to Rocher Capitaine).... No.	6	....	9,871	
Guide cribs (from Ferris Point to Rocher Capitaine).... "	28	....	33,034	
Guide cribs, with lights.... "	7	....	12,054	
				1,198,365
Damages—				
Flooded property.... Acres.	510	20 00	10,200	
Highway bridge at lock, Bascule, 75 feet....	....	....	10,000	
				20,200
				2,725,583
Contingencies, engineering, &c....	....	....	....	272,558
Total....	....	....	....	2,998,141

For analysis and general features refer to page 117, and estimate plan No. 13.

ROCHER CAPTAINE REACH.

Rocher Captaine to Deux Rivières, Miles 283.6 to 296.3.

Surface Elevation 470, Surface below Lock, Elevation 410, Lift 60 feet, 2 Locks 30 feet each.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Rocher Capitaine Locks—					
Excavation, rock, dry	C. yds.	282,435	1 10	310,678	
Excavation, earth, dry	"	52,698	0 30	15,809	
Concrete, lock walls	"	141,304	7 50	1,059,780	
Concrete, core wall, back fill	"	957	7 50	7,177	
Granite masonry	"	306	50 00	15,300	
Equipment—					
Power plant			7,500 00		
Electric power equipment			9,000 00		
Electric light equipment			2,500 00		
Bailing outfit			2,000 00		
Machinery and valves			25,000 00	46,000	
Lock gates	Lbs.	2,894,380	0 06	173,663	
Approaches and Fll—					
Cribwork	C. yds.	67,581	3 00	202,743	
Back fill (behind lockwalls and cribwork) rock	"	384,801	0 50	192,400	
Fill under cribwork, rock	"	2,022	0 50	1,011	
Embankment—					
Earth fill	"	53,648	0 05	2,682	
Rip-rap	"	1,185	1 00	1,185	
					2,028,428
Dam and Regulation—					
Main channel—					
Concrete dam and key-wall	"	15,114	7 50	113,355	
Concrete gate flooring	"	5,044	7 50	37,830	
Excavation, rock, dry	"	12,121	1 10	13,333	
Earth and rock fill	"	78,685	0 50	39,343	
Earth fill	"	17,508	0 15	2,626	
Timber mattress	"	24,880	1 35	33,588	
8 "Stoney" gates	Lin ft.	320	542 66	173,651	
South channel—					
Earth and rock fill	C. yds.	47,648	1 00	47,648	
Earth fill	"	8,831	0 40	3,532	
Timber mattress	"	22,576	1 35	30,477	
					495,383
Channel—					
Excavation, canal prism, rock, wet	"	14,507	3 50	50,775	
Excavation, canal prism, earth, wet	"	7,713	0 25	1,928	
Excavation, canal prism, rock, dry	"	935,387	1 10	1,028,926	
Excavation, canal prism, earth, dry	"	1,019,192	0 30	305,757	
Lighting—					
Lighthouses	No.	5		3,750	
Guide cribs, with lights	"	3		2,953	
					1,394,089
					3,917,900
Contingencies, engineering, &c					391,790
Total					4,309,690

For analysis and general features refer to page 127 and estimate plan No. 13.

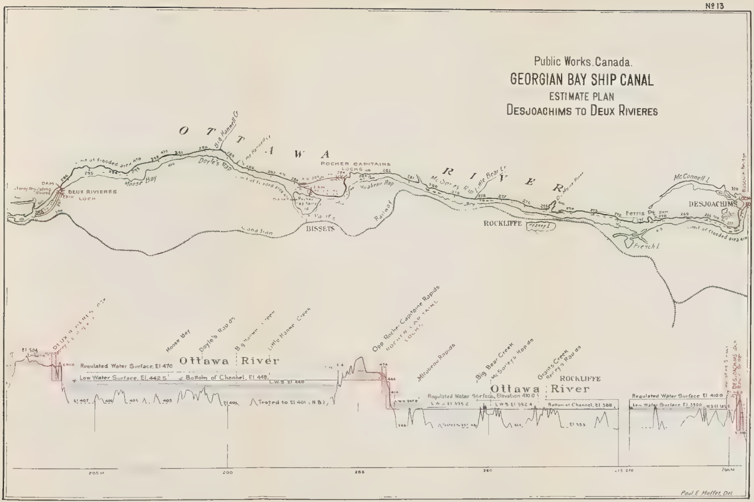
DEUX RIVIERES REACH.

Deux Rivières to Mattawa, Miles 296.3 to 318.0.

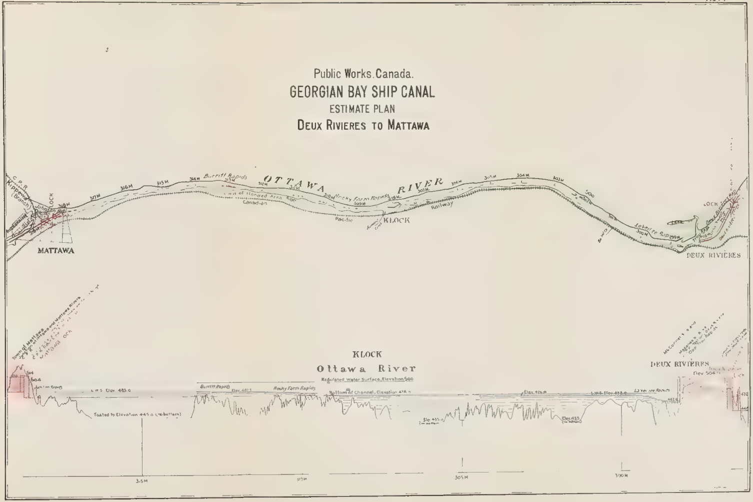
Surface Elevation 500, Surface below Lock, Elevation 470, Lift 30 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Deux Rivières Lock—					
Excavation, rock, dry	C. yds.	96,307	1 10	105,938	
Excavation, earth, dry	"	4,250	0 30	1,275	
Concrete	"	56,468	7 50	423,510	
Granite masonry	"	198	50 00	9,900	
Equipment—					
Power plant			7,500 00		
Electric power equipment			5,000 00		
Electric light equipment			2,000 00		
Bailing outfit			2,000 00		
Machinery and valves			11,000 00	27,500	
Lock gates	Lbs.	1,726,860	0 06	103,612	
Approaches and Fill—					
Cribwork	C. yds.	80,634	3 00	241,902	
Rock fill under cribwork	"	14,774	0 50	7,387	
Back fill (behind lock walls and cribwork) rock	"	43,843	0 50	21,922	
Embankments—					
Excavation, earth, dry	"	10,639	0 30	3,192	
Earth fill	"	172,024	0 05	8,601	
Clay puddle	"	8,000	0 60	4,800	
Rip-rap	"	5,519	1 00	5,519	
					965,058
Dams and Regulation—					
Main channel—					
Concrete dam and wall	"	4,196	7 50	31,470	
Concrete gate flooring	"	7,944	7 50	59,580	
Excavation, earth, dry	"	7,024	0 40	2,809	
Rock and earth fill	"	250,557	0 50	125,279	
Earth fill	"	55,702	0 15	8,355	
Timber mattress	"	37,127	1 35	50,121	
5 "Stoney" gates	Lin. ft.	200	760 24	152,048	
Small dam—					
Concrete	C. yds.	2,982	7 50	22,365	
Excavation, earth, dry	"	1,401	0 30	420	
					452,447
Channel—					
Excavation, canal prism, rock, wet	"	83,412	3 50	291,942	
Excavation, canal prism, rock, dry	"	313,800	1 10	345,180	
Excavation, canal prism, earth, wet	"	15,887	0 25	3,972	
Excavation, canal prism, earth, dry	"	639,385	0 30	191,815	
Lighting—					
Lighthouses	No.	9		11,071	
Guide cribs	"	13		21,060	
Guide cribs with light	"	3		5,476	
					870,516
Damages—					
Flooded property at Deux Rivières				10,000	
Relocating C.P.R. track, 6·5 miles			25 000	162,500	
Rip-rap along C.P.R.	C. yds.	600	1 50	900	
Damages to land and buildings at Klock				9,000	
					182,400
					2,470,421
Contingencies, engineering, &c					247,042
Total					2,717,463

For analysis and general features refer to page 129 and estimate plan No. 14.


Nº 13
Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
DESJOACHIMS TO DEUX RIVIERES
OTTAWA RIVER
DEUX RIVIERES
LOCK
DAM
Moose Bay
Doyle's Rap
ROCHER CAPITAINE
LOCKS
Mirabeau Rap
BISSETS
Railway
McSorley's Rap
Little Bear Cr
ROCKLIFFE
Ferris Pt
McConnell L
DESJOACHIMS
French I
Moose Bay
Doyle's Rapids
Big Hannell Creek
Little Hannell Creek
Opp Rocher Capitaine Rapids
Mirabeau Rapids
Big Bear Creek
McSorley's Rapids
Grants Creek
Rocklife Rapids
Ottawa River
Regulated Water Surface El 470
Low Water Surface El 442.5
Bottom of Channel El 448
Tested to El 401 (N.B.)
Regulated Water Surface, Elevation 410.0
Bottom of Channel El 388
ROCKLIFFE
Regulated Water Surface El 410.0
Low Water Surface El 390.0
Paul E. Moffet, Del.

No 14



Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
DEUX RIVIERES TO MATTAWA
OTTAWA RIVER
Burritt Rapids
Rocky Farm Rapids
Canadian
Pacific
Railway
KLOCK
LOCK
MATTAWA
DEUX RIVIERES
KLOCK
Ottawa River
Regulated Water Surface, Elevation 500
Bottom of Channel, Elevation 478.0
Tested to Elevation 445.0 (no bottom)
DEUX RIVIERES
315M
305M
300M

MATTAWA REACH.

Mattawa to Plain Chant, Miles 318·0 to 320·3.

Surface Elevation 510, Surface below Lock, Elevation 500, Lift 10 feet.

Description.		Quantity.	Price.	Cost	Totals.
			$ cts.	$	$
Mattawa Lock—					
Excavation, rock, dry	C. yds.	12,584	1 10	13,842	
Excavation, earth, dry	"	177,458	0 30	53,237	
Concrete	"	59,886	7 50	449,145	
Granite masonry	"	169	50 00	8,450	
Equipment and machinery				27,500	
Lock gates	Lbs.	1,315,780	0 06	78,947	
Approaches and Fill—					
Cribwork	C. yds.	78,386	3 00	235,158	
Fill under cribwork	"	485	0 50	243	
Fill behind lockwall and cribwork	"	15,670	0 50	7,835	
					874,357
Mattawa Dam and Embankment Weir—					
Concrete, first class	C. yds.	15,050	7 50	112,875	
Excavation, rock, dry	"	16,000	1 10	17,600	
Excavation, cemented material, dry	"	8,000	1 00	8,000	
Excavation, earth, dry	"	4,000	0 40	1,600	
Superstructure	Lin. ft.	950	28 00	26,600	
Unwatering				4,646	
					171,321
Channel—					
Excavation, canal prism, earth, wet	C. yds.	306,538	0 25	76,634	
Excavation, canal prism, earth, dry	"	760,660	0 30	228,198	
Lighting—					
Guide cribs	No.	14		16,255	
					321,087
Damages—					
Damages about Mattawa town, land and buildings				77,810	
Bridges—					
C.P.R., Mattawa (single rolling lift)				50,950	
Pembroke high road at Mattawa (rolling lift)				10,000	
					138,760
					1,505,525
Contingencies, engineering, &c					150,552
Total					1,656,077

For analysis and general features refer to page 131 and estimate plan No. 15.

PLAIN CHANT REACH.

Plain Chant to Les Epines, Miles 320·3 to 326·5.

Surface Elevation 540, Surface below lock, Elevation 510, Lift 30 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Plain Chant Lock—				
Excavation, rock, dry.....C. yds.	73,839	1 10	81,223	
Concrete..... "	63,881	7 50	479,107	
Granite masonry..... "	198	50 00	9,900	
Equipment and machinery.....	.....	.....	27,500	
Lock gates..... Lbs.	1,726,860	0 06	103,612	
Approaches and Fill—				
Cribwork.....C. yds.	78,886	3 00	236,658	
Fill under cribwork..... "	6,861	0 50	3,431	
Fill behind lock walls and cribwork..... "	228,949	0 50	114,475	
				1,055,906
Dam (Plain Chant dam)—				
Concrete, first class.....C. yds.	14,238	7 50	106,785	
Concrete, second class..... "	20,811	4 50	93,649	
Excavation, rock, dry..... "	5,780	1 10	6,358	
Superstructure.....Lin. ft.	1,383	28 00	38,724	
Unwatering.....	.....	.....	20,392	
				265,908
Channel—				
Canal prism, rock, dry.....C. yds.	74,810	1 10	82,291	
Canal prism, rock, wet..... "	8,718	3 50	30,513	
Canal prism, earth, wet..... "	40,992	0 25	10,248	
Lighting—				
Lighthouses.....	3	.....	2,250	
Range lights..... Pair.	1	.....	1,500	
Guide cribs.....	3	.....	4,976	
				131,778
				1,453,592
Contingencies, engineering, &c.....	.....	.....	.....	145,359
Total.....	.....	.....	.....	1,598,951

For analysis and general features refer to page 133 and estimate plan No. 15.

LES EPINES REACH.

Les Epines to Lower Paresseux, Miles 326·5 to 331·5.

Surface Elevation 557, Surface below lock, Elevation 540, Lift 17 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Les Epines Lock—				
Excavation, rock, dry.......C. yds.	12,714	1 10	13,985	
Excavation, earth, dry....... "	293,167	0 30	87,950	
Concrete....... "	61,775	7 50	463,312	
Granite masonry....... "	177	50 00	8,850	
Equipment and machinery (power, &c.).......	....	....	27,500	
Lock gates.......Lbs.	1,442,580	0 06	86,555	
Approaches and Fill—				
Cribwork.......C. yds.	108,029	3 00	324,087	
Fill under cribwork....... "	36,893	0 50	18,447	
Fill behind lock wall and cribwork....... "	9,683	0 50	4,842	1,035,528
Dam—				
Les Epines dam—				
Concrete, first class.......C. yds.	4,311	7 50	32,332	
Concrete, second class....... "	6,068	4 50	27,306	
Excavation, rock, dry....... "	1,712	1 10	1,883	
Superstructure.......Lin. ft.	485	28 00	13,580	
Unwatering.......	....	....	16,248	91,349
Channel—				
Excavation, canal prism, rock, dry.......C. yds.	146,122	1 10	160,734	
Excavation, canal prism, earth, dry....... "	221,552	0 30	66,465	
Lighting—				
Lighthouses.......	2	....	3,769	
Guide cribs.......	10	....	11,550	
Guide cribs with lights.......	8	....	10,045	
Lanterns.......	2	....	500	253,063
				1,379,940
Contingencies, engineering, &c.......	....	....	....	137,994
Total.......	....	....	....	1,517,934

For analysis and general features refer to page 134 and estimate plan No. 15.

LOWER PARESSEUX REACH.

Lower Paresseux to Upper Paresseux, Miles 331·5 to 332·9.

Surface Elevation 617, Surface below lock, Elevation 557; two locks 30 feet each, total lift, 60 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Lower Paresseux Locks—					
Excavation, rock, dry	C. yds.	228,493	1 10	251,342	
Excavation, earth, dry	"	32,038	0 30	9,611	
Concrete	"	146,093	7 50	1,095,697	
Granite masonry	"	306	50 00	15,300	
Equipment and machinery				46,000	
Lock gates	Lbs.	2,894,380	0 06	173,663	
Approaches and Fill—					
Cribwork	C. yds.	49,210	3 00	147,630	
Fill under cribwork	"	2,582	0 50	1,291	
Fill behind lock walls and cribwork	"	170,216	0 50	85,108	
					1,825,642
Dam—					
Concrete, first class	C. yds.	10,050	7 50	76,375	
Concrete, second class	"	16,225	4 50	73,012	
Excavation, rock, dry	"	4,624	1 10	5,086	
Excavation, earth, dry	"	14,116	0 30	4,234	
Superstructure	Lin. ft.	917	28 00	25,676	
					184,383
Channel—					
Excavation, canal prism, rock, dry	C. yds.	428,804	1 10	471,684	
Excavation, canal prism, earth, dry	"	126,517	0 30	37,955	
Guide cribs		2		3,472	
					513,111
					2,523,136
Contingencies, engineering, &c					252,313
Total					2,775,449

For analysis and general features refer to page 134 and estimate plan No. 15

SUMMIT LEVEL.

Upper Paresseux to North Bay, Miles 332·9 to 358·2·

Surface Elevation 677, Surface below lock 617, Life 60 feet; two locks 30 feet each.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Upper Paresseux Locks—					
Excavation, rock, dry	C. yds.	339,433	1 10	373,376	
Concrete	"	144,203	7 50	1,081,522	
Granite masonry	"	319	50 00	15,950	
Equipment and Machinery—					
Power plant			7,500 00		
Electric power equipment			9,000 00		
Electric light equipment			2,500 00		
Bailing outfit			2,000 00		
Machinery valves			25,000 00	46,000	
Lock gates	Lbs.	3,082,460	0 06	184,947	
Approaches and Fill—					
Cribwork	C. yds.	48,767	3 00	146,301	
Fill under cribwork	"	23,822	0 50	11,911	
Fill behind lock walls and cribwork	"	90,108	0 50	45,054	
					1,905,061
Dams and Regulating Culverts—					
Talon Chute Dam—					
Concrete, first class	C. yds.	9,876	7 50	74,070	
Concrete, second class	"	14,559	4 50	65,515	
Excavation, rock, dry	"	3,761	1 10	4,137	
Superstructure	Lin. ft.	1,125	28 00	31,500	
Unwatering				13,190	
Upper Paresseux Dam—					
Concrete, first class	C. yds.	3,262	7 50	24,465	
Concrete, second class	"	3,035	4 50	13,657	
Excavation, rock, dry	"	1,478	1 10	1,626	
Excavation, earth, dry	"	493	0 30	148	
Superstructure	Lin. ft.	693	28 00	19,404	
Upper Paresseux Regulating Culvert—					
Concrete	C. yds.	850	7 50	6,375	
2 "Stoney" gates	Lbs.	70,000	0 06	4,200	
					258,287
Channel—					
Excavation—					
Canal prism, rock, dry	C. yds.	4,622,930	1 10	5,085,223	
Canal prism, earth, dry	"	848,322	0 30	254,497	
Lighting—					
Lighthouses		6		8,764	
Guide cribs		25		25,063	
Guide cribs with light		20		26,532	
Range lights	Pair.	2		3,000	
					5,403,079
Dams—					
1. Excavation, earth, dry	C. yds.	1,465	0 40	586	
Earth fill	"	2,090	0 25	523	
Earth fill	"	2,090	0 25	523	
Puddle	"	1,045	0 60	627	
2. Excavation, earth, dry	"	1,720	0 40	688	
Earth fill	"	3,230	0 25	808	
Puddle	"	1,615	0 60	969	
3. Excavation, earth, dry	"	3,000	0 40	1,200	
Earth fill	"	6,440	0 25	1,610	
Puddle	"	3,220	0 60	1,932	
4. Excavation, earth, dry	"	820	0 40	328	
Earth fill	"	1,700	0 25	425	
Puddle	"	850	0 60	510	

SUMMIT LEVEL—*Concluded.*

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Dams—(Continued)—				
5. Excavation, earth, dry............... C. yds.	2,000	0 40	800	
Earth fill........................... "	3,700	0 25	925	
Puddle............................ "	1,850	0 60	1,110	
6. Excavation, earth, dry.............. "	4,300	0 40	1,720	
Earth fill........................... "	7,150	0 25	1,788	
Puddle............................ "	3,600	0 60	2,160	
7. Excavation, earth, dry.............. "	3,400	0 40	1,360	
Earth fill........................... "	7,450	0 25	1,863	
Puddle............................ "	3,725	0 60	2,235	
8. Excavation, earth, dry.............. "	2,900	0 40	1,160	
Earth fill........................... "	4,700	0 25	1,175	
Puddle............................ "	2,350	0 60	1,410	
9. Excavation, earth, dry.............. "	1,150	0 40	460	
Earth fill........................... "	1,400	0 25	350	
Puddle............................ "	700	0 60	420	
10. Excavation, rock, dry.............. "	790	1 25	987	
Earth fill........................... "	3,050	0 40	1,220	
Puddle............................ "	1,500	0 60	900	
				32,249
North Bay Lock (lift 29 feet; surface elev. below lock 648.)				
Excavation, rock, dry.................... C. yds.	127,020	1 10	139,722	
Excavation, earth, dry.................. "	9,130	0 30	2,739	
Concrete............................... "	42,710	7 50	320,325	
Granite masonry....................... "	203	50 00	10,150	
Equipment and Machinery........................	....	....	27,500	
Lock gates...............................	....	....	106,470	
Approaches—				
Cribwork, North Bay Lock............... C. yds.	49,295	3 00	147,885	
				754,791
Damages—				
Talon Lake and Kai-bus-kong.................	....	....	10,000	
Bridges—				
Callender high road at North Bay lock, rolling lift.	....	....	10,000	
				20,000
				8,373,467
Contingencies, engineering, &c.......................	....	....	....	837,346
				9,210,813

For analysis and general features refer to page 136 and estimate plan No. 16.

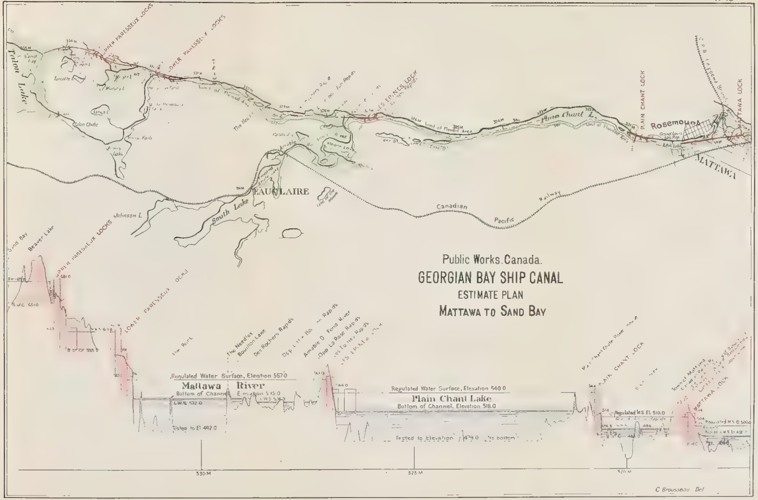
AMABLE DU FOND FEEDER CANAL.

Proposition for the Delivery of 700 cubic feet per second.

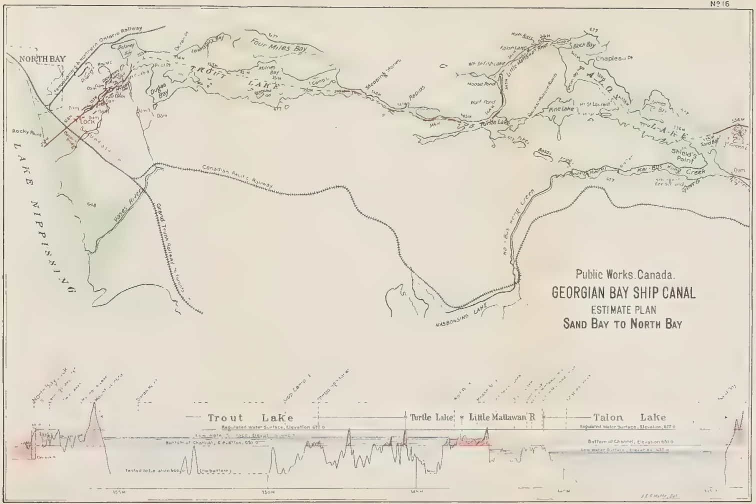
Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Dam at Gravelle Chute—				
Unwatering			12,410	
Earth fill ... C. yds.	134,505	0 25	33,626	
Rock fill ... "	47,888	1 50	71,832	
Hand laid wall ... "			7,962	
Rip-rap ... "	2,618	4 00	10,472	
Head works of canal and regulating works at Gravelle Chute—				
Concrete ... C. yds.	644	9 00	5,796	
Steel ... Lbs.	5,840	0 05	292	
Cast iron ... "	2,332	0 04	93	
Gates and operating machinery			1,000	
Flume work from Gravelle Chute to Sparks Creek—				
Wooden flume ... Foot run.	27,350	11 80	322,730	
Trestle work for above			36,240	
Earth excavation ... C. yds.	20,465	0 30	6,139	
Lined open channel, approaches to and exits from two tunnels—				
Earth excavation ... C. yds.	150,060	0 35	52,511	
Concrete lining ... "	2,785	9 00	25,065	
Tunnel 1—				
Tunnelling, timbering, &c ... Foot run.	1,670	35 00	58,450	
Tunnel 2—				
Tunnelling, timbering, &c ... Foot run.	1,620	35 00	56,700	
Unlined open channel, head of Sparks Creek—				
Earth excavation ... C. yds	113,791	0 30	34,197	
Improvements to water course of Sparks Creek, from canal discharge to Talon Lake—				
Reservoirs, (From Hydraulic Engineers' Report)				
Reserve dam at Mink Lake			38,250	
Reserve dam at Indian River (probable)			23,089	
Reserve dam at Three Mile Lake			16,377	
Reserve dam at Tea Lake			46,034	
Reserve dam at Manitou Lake			28,449	
				897,714
Contingencies, engineering, &c				89,771
Total				987,485

For analysis and general features refer to page 159.

N°15


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
MATTAWA TO SAND BAY
Talon Lake
Sand Bay
Turcotte L.
Talon Chute
UPPER PARESSEUX LOCKS
LOWER PARESSEUX LOCKS
LES EPINES LOCK
Plain Chant L.
PLAIN CHANT LOCK
Rosemount
MATTAWA LOCK
MATTAWA
EAU CLAIRE
Smith Lake
Johnson L.
Canadian Pacific Railway
Beaver Lake
Regulated Water Surface, Elevation 557.0
Mattawa River
Bottom of Channel, Elevation 515.0
Regulated Water Surface, Elevation 540.0
Plain Chant Lake
Bottom of Channel, Elevation 518.0
Tested to Elevation
Regulated W.S. EL 510.0
330 M
325 M
320 M
C. Brousseau Del.

No. 16


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
SAND BAY TO NORTH BAY
NORTH BAY
LAKE NIPPISSING
TROUT LAKE
Four Miles Bay
Canadian Pacific Railway
Grand Trunk Railway to Toronto
Temiscaming & Northern Ontario Railway
Turtle Lake
Talon Lake
Chapleau Pt
Pine Lake
Shield's Point
Kai-Bus Kong Creek
NASBONSING LAKE
Rocky Point
LOCK
Trout Lake
Turtle Lake
Little Mattawan R
Talon Lake
Regulated Water Surface, Elevation 677.0
Bottom of Channel, Elevation 651.0

NIPISSING REACH.

North Bay to the Chaudière lock, Miles 358.2 to 389.9.

Surface Elevation 648, Surface below lock, Elevation 624, Lift 24 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Channel—					
Excavation, canal prism, rock, wet	C. yds.	231,455	3 50	810,093	
Excavation, canal prism, rock, dry	"	407,175	1 10	447,893	
Excavation, canal prism, earth, wet	"	154,062	0 25	38,515	
Excavation, canal prism, earth, dry	"	983,011	0 30	294,903	
Lighting—					
Lighthouses	No.	11		12,957	
Guide cribs	"	1		778	
Lanterns	"	2		500	
					1,605 639
Chaudière Lock—					
Excavation, lock pit, rock, dry	C. yds.	113,462	1 10	124,808	
Concrete	"	42,389	7 50	317,917	
Granite masonry	"	188	50 00	9,400	
Equipment and machinery				27,500	
Lock gates				95,266	
Approaches and Fills—					
Cribwork	C. yds.	61,908	3 00	185 724	
Fill under cribwork, rock	"	4,382	0 50	2,191	
Back fill, behind lockwalls and cribwork	"	95,000	0 50	47,500	
					810,306
Dams and Regulation—					
Little Chaudière (3 dams)—					
Concrete	C. yds.	1,034	7 50	7,755	
Excavation, rock, dry	"	107	1 10	118	
Rock fill	"	841	1 00	841	
Unwatering				3,000	
Big Chaudière—					
Concrete	C. yds.	763	7 50	5,723	
Excavation, rock, dry	"	1,390	1 10	1,529	
3 "Stoney" gates, 4 piers				57,253	
Unwatering				5,000	
					81,219
Entrance and Dockage Facilities, North Bay—					
Cribwork, entrance Rocky Point	C. yds.	139,476	3 00	418,428	
Dockage facilities, North Bay—					
Cribwork (2,000 lineal feet)	"	32,333	3 00	96,999	
Rock filling behind cribwork	"	53,333	0 50	26,666	
					542,093
Damages—					
To land and buildings at Callender				3,000	
To land and buildings at North Bay				124,690	
Dockage at Callender				15,000	
Dockage at North Bay				5,000	
Dockage at Cache Bay				2,000	
Dockage at Sturgeon Falls				2,000	
Flooded land on Lake Nipissing shore				10,000	
Raised C.P.R. track, North Bay	C. yds.	15,000	0 40	6,000	
Bridges—					
C.P.R., North Bay, double track, rolling lift				95,320	
					263,010
					3,302,267
Contingencies, engineering, &c					330,227
Total					3,632,494

For analysis and general features refer to page 141 and estimate plan No. 17.


LAKE NIPISSING
NORTH BAY
LOCK
Grand Manitou Islands
Goose Ids
Sandy Island
Burnt Island
Blueberry
McDonald Ids.
Little Manitou Ids
Rocky Point
Franks Bay
HEAD OF FRENCH RIVER
Long Lake
Restoul River
Bass Lake
South Bay
East Bay
Fish Bay
LOCK
Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
NORTH BAY TO CHAUDIERE FALLS
CHAUDIERE FALLS LOCK
NORTH BAY LOCK
Highway Bascule Bridge
Lake Nipissing
Regulated Water Surface, Elevation 648.0
Low Water Surface, Elevation 638.0
Bottom of Channel, Elevation 626.0
Tested to Elevation 590.0 (No bottom)
Elev 566.0 (No bottom)
385M
380M
375M
370M
365M
360M
C Brousseau Del

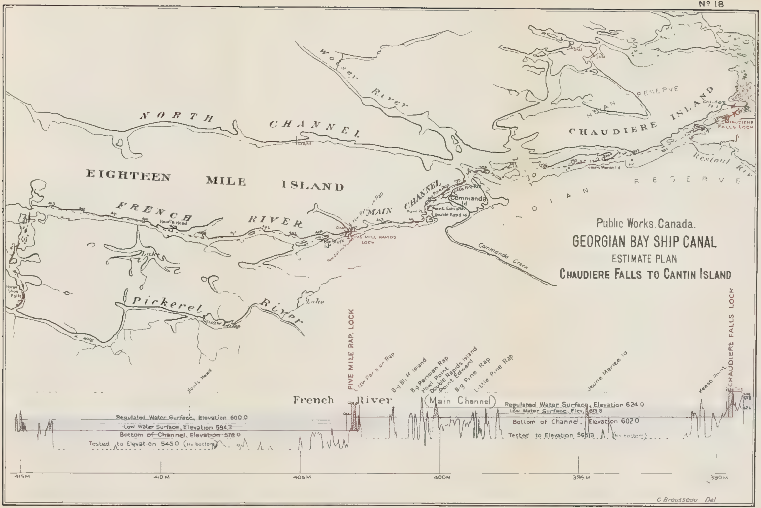
FIVE MILE RAPID REACH.

Chaudière lock to Five Mile Rapid, Miles 389·9 to 403·4.

Surface Elevation 624, Surface below lock, Elevation 600, Lift 24 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Channel—					
Excavation, canal prism, rock, wet	C. yds.	338,086	3 50	1,183,301	
Excavation, canal prism, rock, dry	"	845,462	1 10	930,008	
Unwatering Five Mile Rapid				4,500	
Lightnig—					
Lighthouses	No.	3		2,250	
Guide cribs	"	26		11,393	
Guide cribs with lights	"	29		29,329	
					2,160,781
Five Mile Rapid Lock—					
Excavation, lock pit, rock, dry	C. yds.	83,881	1 10	92,269	
Concrete	"	56,000	7 50	420,000	
Granite masonry	"	188	50 00	9,400	
Unwatering				14,000	
Equipment and machinery				27,500	
Lock gates				95,266	
Approaches and Fills—					
Cribwork	C. yds.	62,895	3 00	188,685	
Rock fill under cribs	"	40,372	0 50	20,186	
Back fill behind lock wall and cribwork	"	130,000	0 50	65,000	
					932,306
Dams and Regulations—					
Eighteen Mile Island—					
Concrete	C. yds.	1,592	7 50	11,940	
Excavation, rock, dry	"	1,035	1 10	1,138	
Timber	B. M.	36,798	40 00	1,472	
Steel	Lbs.	43,014	0 06	2,581	
Car and lifting gear	"	7,000	0 06	420	
Timber dam	C. yds.	411	3 00	1,233	
Unwatering				5,000	
Five Mile Rapid—					
Concrete	C. yds.	934	7 50	7,005	
Excavation, rock, dry	"	5,876	1 10	6,464	
Timber	B. M.	27,621	40 00	1,105	
Steel	Lbs.	33,872	0 06	2,032	
Car and lifting gear	"	7,000	0 06	420	
Rock fill	C. yds.	27,075	1 00	27,075	
Earth fill	"	3,762	0 50	1,881	
					69,766
					3,162,853
Contingencies, engineering, &c					316,285
Total					3,479,138

For analysis and general features refer to page 143 and estimate plan No. 18.


Nº 18
NORTH CHANNEL
EIGHTEEN MILE ISLAND
FRENCH RIVER
MAIN CHANNEL
Commanda Id
Point Edward
Double Rapid Id
Wolseley River
INDIAN RESERVE
CHAUDIERE ISLAND
CHAUDIERE FALLS LOCK
Restoul River
Commanda Creek
FIVE MILE RAPIDS LOCK
Big Bluff Id
Pickerel River
Squaw Lake
Lake
Horse Shoe Falls
DAM
Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
CHAUDIERE FALLS TO CANTIN ISLAND
FIVE MILE RAP. LOCK
CHAUDIERE FALLS LOCK
Howls Head
Little Parisien Rap
Big Bluff Island
Big Parisian Rap
Howl Point
Double Rapids Island
Point Edward
Big Pine Rap
Little Pine Rap
Jeune Mariee Id
French River (Main Channel)
Regulated Water Surface, Elevation 600.0
Low Water Surface, Elevation 594.3
Bottom of Channel, Elevation 578.0
Tested to Elevation 545.0 (no bottom)
Regulated Water Surface, Elevation 624.0
Low Water Surface, Elev. 613.3
Bottom of Channel, Elevation 602.0
Tested to Elevation 565.8 (no bottom)
415 M
410 M
405 M
400 M
395 M
390 M
C. Brousseau Del

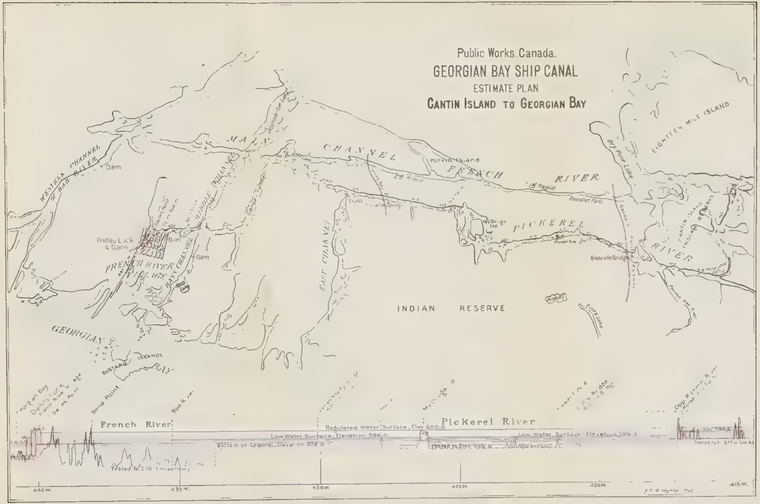
PICKEREL RIVER REACH.

Five Mile Rapid Lock to the Georgian Bay, Miles 403·4 to 442·6.

Surface elevation 600, Surface below lock, Elevation 578·51, Life 21·5 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Channel (to mile 440·5)—				
Excavation, canal prism, earth, dry........C. yds.	64,922	0 30	19,476	
Excavation, canal prism, rock, wet........ "	750,371	3 50	2,626,298	
Excavation, canal prism, rock, dry........ "	918,438	1 10	1,010,282	
Unwatering Horseshoe........................	....	....	7,500	
Lighting—				
Lighthouses.......................... No.	19	....	16,522	
Guide cribs.......................... "	21	....	9,753	
Guide cribs with light.................. "	56	....	37,007	
Lanterns.............................. "	2	....	500	
Range lights.......................... Pair.	3	....	4,500	
				3,731,838
Dalles Lock—				
Excavation, lock pit, rock, dry............C. yds.	8,650	1 10	9,515	
Concrete.............................. "	80,465	7 50	603,487	
Granite masonry...................... "	222	50 00	11,100	
Equipment and mnchinery..................	....	....	27,500	
Lock gates..............................	....	....	92,665	
Unwatering lock and dam..................	....	....	121,000	
Approaches and Fills—				
Cribwork..............................C. yds.	115,000	3 00	345,000	
Fill under cribwork...................... "	59,507	0 50	29,753	
Back fill behind lockwall and cribwork..... "	400,000	0 50	200,000	
				1,440,020
Dams—				
Dalles Lock dam—				
Concrete..........................C. yds.	9,313	7 50	69,848	
Excavation, rock, dry............... "	916	1 10	1,007	
Tramway Point dam—				
Concrete.......................... "	938	7 50	7,035	
Excavation, rock, dry............... "	140	1 10	154	
Excavation, earth, dry.............. "	42	0 40	17	
Unwatering..........................	....	....	1,000	
Bass Creek dam—				
Concrete..........................C. yds.	7,155	7 50	53,663	
Excavation, rock, dry............... "	654	1 10	719	
Excavation, earth, dry.............. "	830	0 40	332	
Unwatering..........................	....	....	3,500	
Bad River dam—				
Concrete..........................C. yds.	8,600	7 50	64,500	
Excavation, rock, dry............... "	433	1 10	476	
Unwatering..........................	....	....	2,500	
Eastern Outlet dam—				
Concrete..........................C. yds.	2,013	7 50	15,098	
Excavation, rock, dry............... "	525	1 10	577	
Unwatering..........................	....	....	3,500	
				223,926
Damages—				
Bridges—				
C.P.R. crossing Pickerel River..............	....	....	150,000	
James Bay Ry. crossing Pickerel River.......	....	....	180.000	
				330,000
Entrance French River (miles 440·5 to 442·6)—				
Excavation, rock, wet...................C. yds.	210,446	3 50	736,561	
Excavation, rock, dry.................. "	1,556	1 10	1,712	
Lighting—				
Range lights.......................... Pair.	1	....	1,800	
Lanterns.............................. "	2	....	500	
Approaches—				
Cribwork..............................C. yds.	15,089	3 00	45,267	
				785,840
				6,511,624
Contingencies, engineering, &c..................	....	....	....	651,162
Total..	....	....	....	7,162,786

For analysis and general features refer to page 146 and estimate plans Nos. 18 and 19.


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
CANTIN ISLAND TO GEORGIAN BAY
WESTERN CHANNEL OF BAD RIVER
Dam
MAIN CHANNEL
MIDDLE CHANNEL
FRENCH RIVER
1st Rapid
Recollet Falls
Potvin Island
2nd Rapid
PICKEREL RIVER
EIGHTEEN MILE ISLAND
Dry Pine Lake
CANTIN ISLAND INDIAN RESERVE
Dalles Lock & Dams
FRENCH RIVER VILLAGE
BASS CHANNEL
EAST CHANNEL
INDIAN RESERVE
Bascule Bridge
GEORGIAN BAY
BUSTARD ISLANDS
Bend Point
Bad River
French River
Pickerel River
Regulated Water Surface, Elev 600.0
Low Water Surface, Elevation 584.0
Low Water Surface Elevation 586.5
Bottom of Channel, Elevation 578.0
Tested to Elev 565.0
Tested to 545 (no bottom)
440M
435M.
430M
425M.
420M
415M.
J. E. Motte Drt

SUMMARY OF ESTIMATED COST, BY REACHES, (VIA LAKE ST. LOUIS).

—	Mile.	Locks.	Dams and Regulation.	Channels.	Damages.	Totals.	Total Cost with Contingencies &c.
		$	$	$	$	$	$
Montreal reach	0 to 5	1,090,700	64,000	1,352,300	1,352,000	3,859,000	4,244,827
St. Louis reach	5 to 25	1,093,000	12,200	11,070,800	377,000	12,553,000	13,808,239
Oka reach	25 to 49	784,800	360,800	937,300	251,100	2,334,000	2,567,365
Pointe Fortune reach	49 to 60	1,477,400	361,900	1,880,900	140,600	3,860,800	4,246,905
Ottawa reach	60 to 121	989,600	207,800	3,750,900	1,221,500	6,169,800	6,786,849
Hull reach	121 to 122	929,700	5,700	730,400	658,000	2,323,800	2,556,153
Aylmer reach	122 to 154	673,700	406,600	2,938,800	1,580,000	5,599,100	6,159,043
Arnprior reach	154 to 174	818,200	477,700	1,421,400	28,300	2,745,600	3,020,268
Portage du Fort reach	174 to 187	919,400	596,200	383,900	132,800	2,032,300	2,235,516
Rocher Fendu reach	187 to 190	1,071,800	352,400	49,400	8,200	481,800	1,630,026
Coulonge reach	190 to 209	1,052,300	588,500	2,294,900	4,700	3,940,400	4,334,461
Pembroke reach	209 to 265	1,030,800	209,600	2,984,500	175,300	4,400,200	4,840,099
DesJoachims reach	265 to 284	1,419,123	87,895	1,198,365	20,200	2,725,583	2,998,141
Rocher Capitaine reach	284 to 296	2,028,428	495,383	1,394,089	....	3,917,900	4,309,690
Deux Rivieres reach	296 to 318	965,058	452,447	870,516	182,400	2,470,421	2,717,463
Mattawa reach	318 to 320	874,357	171,321	321,087	138,760	1,505,525	1,656,077
Plain Chant reach	320 to 326	1,055,906	265,908	131,778	....	1,453,592	1,598,951
Les Epines reach	326 to 331	1,035,528	91,349	253,063	....	1,379,940	1,517,934
Lower Paresseux reach	331 to 333	1,825,642	184,383	513,111	....	2,523,136	2,775,449
Summit reach	333 to 358	2,659,852	290,536	5,403,079	20,000	8,373,467	9,210,813
Nipissing reach	358 to 390	810,306	81,219	2,147,732	263,010	3,302,267	3,632,494
Five Mile Rapid reach	390 to 403	932,306	69,766	2,160,781	....	3,162,853	3,479,138
Pickerel River reach	403 to 442	1,440,020	223,926	4,517,678	330,000	6,511,624	7,162,786
		26,977,926 30 p.c.	6,057,533 7 p.c.	48,706,779 55 p.c.	6,883,870 8 p.c.	88,626,108	97,488,687
Storage reservoirs, &c.	....	....	....	....	....	....	2,200,000
Total cost, say	....	....	....	....	....	....	99,689,000

Construction of locks, dams, channels, piers, lighting, damages	$ 88,626,108
Contingencies, engineering, administration, say 10 p.c.	8,862,892
Storage of flood waters, regulation basins, telephones, &c.	2,200,000
Total	$ 99,689,000
Feeder at Summit, when required	$ 987,485

SUMMARY OF ESTIMATE OF COST, BY ITEMS.

ROUTE A (LAKE ST. LOUIS, STE. ANNE, &c.) *See* page 328

Description.		Quantity.	Unit Prices.	Cost.
				$
Rock excavation, sub-marine	C. yds.	8,322,554	$1.50, $3,00 and $3.50	23,982,780
Rock excavation, dry	"	18,574,496	$1.00 and $1.50	19,587,750
Earth excavation, dredging	"	8,935,667	20c., 25c., 30c. and 35c.	2,140,073
Earth excavation, dry	"	10,836,537	20c., 30c., 35c., and 45c.	3,223,690
Concrete in dams, locks and entrance piers	"	1,841,259	$7.50	13,810,493
Concrete in dams, second class	"	60,698	$4.50	273,139
Granite masonry in locks	"	2,474	$50.00	123,700
Rock fill (dams, embankments and behind cribs and walls)	"	7,880,652	50c.	3,940,337
Rock fill (rip-rap and borrow pit)	"	510,088	$1.00	510,088
Bank lining	"	114,300	$2.00	228,600
Earth fill (dams, embankments and back of walls)	"	3,770,078	5c., 10c., 15c., 25c., 30c., 50c. and 60c.	984,229
Cribwork	"	1,910,102	$3.00 and $3.50	6,191,405
Timber mattress	"	84,583	$1.35	114,186
Stop-logs, regulating works and machinery				1,849,680
Unwatering				354,976
Lock gates (steel)	Lbs.	43,501,767	6c.	2,610,106
Equipment and power				875,920
Bridges, railway crossings				1,462,882
Lighthouses, guide piers, lighting				879,734
Damages to land and water supply powers, drainage, railway and highway diversions, &c				5,482,340
				88,626,108
Contingencies, engineering, administration, say 10 per cent				8,862,892
Storage of flood waters, regulation basins, telephones, &c				2,200,000
Total				99,689,000
Feeder at Summit, when required				987,485

ROUTE B (RIVIERE DES PRAIRIES, &c.) *See* page 328.

Total estimated cost			93,890,000

A COMPARISON OF SAND BAY LINE WITH AMABLE DU FOND ROUTE.

Between Lake Talon and Plain Chant Lake.

Material.	Sand Bay Line.			Amable du Fond Route.		
	Quantity.	Price.	Amount.	Quantity.	Price.	Amount.
	Cub. yds.	$ cts.		Cub. yds.	$ cts.	$
Rock, dry	2,767,957	1 10	3,044,753	3,065,610	1 10	3,372,171
Rock, wet	....	....	....	13,000	3 50	52,500
Earth, dry	685,189	0 30	205,557	1,225,763	0 30	367,722
Rock fills	333,703	0 50	166,851	507,079	0 50	253,539
Rock fills (hand laid)	8,026	1 50	12,039	....	....	....
Earth fills	10,792	0 25	2,698	214,340	0 25	53,585
Concrete	395,114	7 50	2,963,355	398,850	7 50	2,991,375
Cribwork	225,318	3 00	675,954	215,955	3 00	647,865
C. P. Ry. diversion	....	....	....	....	....	380,480
Two swing bridges, road crossings	....	....	....	....	....	90,000
Road diversion near Eau Claire	....	....	....	....	....	2,000
			7,071,207			8,211,243
Contingencies, engineering, &c	....	....	707,120	....	....	821,124
Total	....	....	7,778,327	....	....	9,032,367
Difference in favour of Sand Bay line	....	....	1,254,040			

ESTIMATE FROM NORTH BAY TO FOOT OF UPPER PARESSEUX.

With Summit Grade Elevation—626·0.

Summit Reach lowered to Lake Nipissing level.

Locality and Description.	Quantity.	Price.	Amount.
	C. yds.	$ cts.	$
Excavation, rock, dry—			
Canal prism (from final estimate)	4,614,853	1 10	5,076,338
New quantity through North Bay lock site	321,870	1 10	354,057
New quantity through changing grade from 651·0 to 626·0	9,333,148	1 20	11,199,776
New lock pit, Upper Paresseux (single)	134,500	1 10	147,950
Excavation, earth, dry—			
Canal prism (from final estimate)	1,766,147	0 30	529,844
New quantity through North Bay lock site	14,741	0 30	4,422
Concrete—			
Lock, Upper Paresseux, single (approximate)	70,000	7 50	525,000
Granite masonry—			
Lock, Upper Paresseux, single	198	50 00	9,900
Approaches and fills—			
Upper Pasesseux, cribwork (approximate)	35,074	3 00	105,222
Dams—			
Talon Chute—			
Concrete, first class	2,880	7 50	21,600
Concrete, second class	2,016	4 50	9,072
Excavation, rock, dry (approximate)	1,880	1 10	2,068
Superstructure (lineal feet)	640	28 00	17,920
Unwatering			5,000
Equipment, machinery, lock gates, &c.			135,000
Bridges—			
Canadian Pacific railway, near North Bay			95,320
Callender, high road (apprixomate)			30,000
Lighting			63,359
Damages			10,000
Dockage facilities, North Bay—			
Cribwork (2,000 lineal feet)	32,333	3 00	96,999
Rock fill behind cribwork	53,333	0 50	26,666
Total			18,465,515
Contingencies, engineering, administration, &c.			1,846,552
Total cost			20,312,067

Grade 651.0 = $ 10,685,326
Grade 626.0 = 20,312,067

$ 9,626,741, difference in favour of the Trout and Talon Lake summit

SUMMARY OF ESTIMATED COST.

French River section, North Bay to Lake Huron, Mileage 358.2 to 442.6.

Nipissing reach (mileage 358.2 to 389.9)	$ 3,302,267
Five Mile Rapid reach (389.9 to 403.4)	3,162,863
Pickerel reach and Lake entrance (403.4 to 442.6)	6,511,624
	$12,976,744
Contingencies, engineering, administration, 10 per cent	1,297,676
Total,	$14,274,420

ALTERNATIVE ROUTE ENTRANCE TO MONTREAL THROUGH BACK RIVER (RIVIERE DES PRAIRIES).

PRAIRIES BEACH.

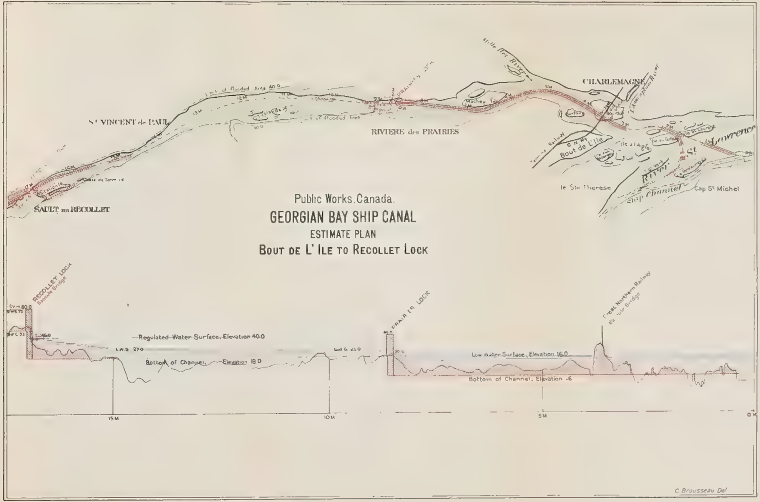
Ship Channel to Sault au Recollet, Miles 0 to 17.

Surface Elevation 40, Surface below lock, Elevation 16, Lift 24 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Prairies Lock—					
Excavation, rock, dry	C. yds.	68,360	1 00	68,360	
Unwatering pit				10,000	
Concrete, lockwalls, &c.	C. yds.	42,540	7 50	319,000	
Entrance piers, cribwork	"	57,914	3 50	202,700	
Entrance piers, concrete wall	"	8,000	7 50	60,000	
Entrance piers, rock fill, back of wall	"	48,000	0 50	24,000	
Lock gates	Tons.	742	120 00	89,040	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery.	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, &c.				10,000	812,900
Dam and Regulation—					
Dam, rock, loose	C. yds.	92,772	0 50	46,386	
Dam, earth face	"	23,193	0 25	5,798	
Stop-log sluice				60,550	
Operating machines	Each.	2	700 00	1,400	114,200
Channel—					
Excavation, rock, wet	C. yds.	984,777	3 00	2,954,331	
Excavation, rock, dry	"	202,023	1 00	202,023	
Excavation, earth, wet	"	3,989,258	20c. & 35c.	808,354	
Excavation, earth, dry	"	511,384	0 35	178,985	
Bank lining	"	4,000	2 00	8,000	
Range lights, marking piers, &c.				44,400	4,960,093
Damages—					
Land and rights				408,625	
Water powers				30,000	
Highway diversions				16,000	
Railway bridges				120,000	574,625
					5,697,800
Contingencies, engineering, &c.					569,780
Totals					6,267,580

For analysis and general features refer to page 100 and estimate plan No. 20.

Nº 20


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
Bout de L' Ile to Recollet Lock
CHARLEMAGNE
St VINCENT de PAUL
RIVIERE des PRAIRIES
SAULT au RECOLLET
Mille Iles River
Bout de L'Ile
St Lawrence River
Ship Channel
Cap St Michel
RECOLLET LOCK
Bascule Bridge
PRAIRIES LOCK
Great Northern Railway
Regulated Water Surface, Elevation 40.0
Bottom of Channel, Elevation 18.0
Low Water Surface, Elevation 16.0
Bottom of Channel, Elevation -6
15 M
10 M
5 M
0 M
C. Brousseau Del

ALTERNATIVE ENTRANCE TO MONTREAL—(*Continued*).

BACK RIVER (RIVIERE DES PRAIRIES) RECOLLET REACH.

Sault au Recollet to Pointe Fortune, Miles 17 to 49.

Surface Elevation 75, Surface below Lock, Elevation 40, Lift 35 feet.

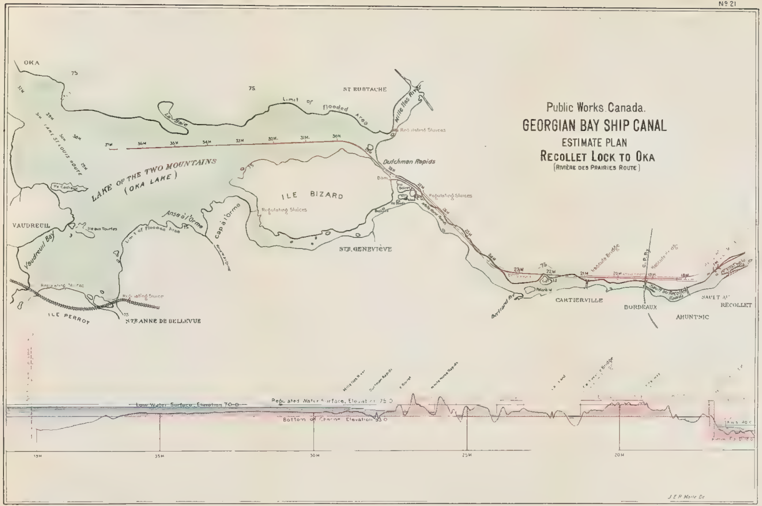
Description.	Quantities.	Price.	Cost.	Totals.
		$ cts.	$	$
Recollet Lock—				
Excavation, rock, dry.....C. yds.	77,600	1 00	77,600	
Excavation, earth, dry..... "	49,300	0 35	17,300	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, &c.....C. yds.	70,983	7 50	532,400	
Entrance piers, cribwork..... "	108,000	3 50	378,000	
Entrance piers, concrete wall..... "	8,000	7 50	60,000	
Entrance piers, rock fill, back of wall..... "	48,000	0 50	24,000	
Lock gates..... Tons.	890	120 00	106,800	
Gate operating machines..... Each.	8	500 00	4,000	
Filli ng and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights.....	.....	.....	10,000	
Bollards, ladders, life chains, &c.....	.....	.....	10,000	
				1,245,940
Dam and Regulation—				
Stop-log sluice.....	.....	.....	357,444	
Operating machines..... Each.	15	700 00	10,500	
				367,944
Channel—				
Excavation, rock, wet.....C. yds.	538,007	3 00	1,614,021	
Excavation, rock, dry..... "	407,982	1 00	407,982	
Excavation, earth, wet..... "	5,015,326	0 20	1,003,065	
Excavation, earth, dry..... "	5,343,998	0 35	1,870,400	
Embankment, loose rock..... "	26,248	0 50	13,124	
Embankment, earth..... "	3,250,573	15c. & 25c.	488,242	
Bank lining..... "	106,000	2 00	212,000	
Range lights, marking piers, &c.....	.....	.....	40,700	
				5,649,534
Damages—				
Land and rights.....	.....	.....	368,305	
Water powers.....	.....	.....	5,000	
Railway bridges.....	.....	.....	65,000	
Highway bridges.....	.....	.....	75,000	
				513,305
				7,776,600
Contingencies, engineering, &c				777,660
Total.....	.....	.....	.....	8,554,260

The two entrances to Montreal, common point at Pointe Fortune, compare in cost as follows:—

Montreal, Ste Anne to Pointe Fortune.....	$ 20,620,431
Ship channel, Back River to Pointe Fortune.....	14,821,840
Difference.....	$ 5,798,591

For analysis and general features refer to page 101 and estimate plan No. 21

No 21


Public Works Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
RECOLLET LOCK TO OKA
(RIVIÈRE DES PRAIRIES ROUTE)
OKA
ST EUSTACHE
Limit of Flooded Area
Mille Iles River
Regulating Sluices
Dutchman Rapids
LAKE OF THE TWO MOUNTAINS
(OKA LAKE)
ILE BIZARD
STE. GENEVIÈVE
VAUDREUIL
Vaudreuil Bay
Anse à l'Orme
Cap à l'Orme
ILE PERROT
STE ANNE DE BELLEVUE
CARTIERVILLE
BORDEAUX
AHUNTSIC
SAULT AU RECOLLET
Low Water Surface, Elevation 70.0
Regulated Water Surface, Elevation 75.0
Bottom of Channel Elevation 55.0
35M
30M
25M
20M

PORTAGE DU FORT REACH VIA CALUMET CHANNEL.

Chenaux Rapids to Mountain Chute, Miles 174 to 184—(Main Line Chainage, Continued).

Surface Elevation 280, Surface below lock, Elevation 245, Lift 35 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Chenaux Lock—				
Excavation, rock, dry .... C. yds.	174,055	1 00	174,100	
Unwatering pit	....	....	10,000	
Concrete, lock walls, &c .... C. yds.	37,900	7 50	284,250	
Entrance piers, cribwork .... "	60,791	3 50	212,770	
Entrance piers, concrete wall .... "	7,000	7 50	52,500	
Entrance piers, rock fill .... "	78,260	0 50	39,130	
Lock gates .... Tons.	890	120 00	106,800	
Gate operating machines .... Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lighting	....	....	10,000	
Bollards, ladders, life chains, &c	....	....	10,000	
				919,390
Dam and Regulations—				
Dam, rock, loose .... C. yds.	553,586	0 50	276,793	
Dam, earth, face .... "	138,396	0 50	69,198	
Dam, borrow pit, rock .... "	125,000	1 00	125,000	
Stop-log sluices	....	....	123,100	
Operating machines .... Each.	3	700 00	2,100	
				596,191
Channel—				
Excavation, rock, wet .... C. yds.	2,867	3 00	8,601	
Excavation, rock, dry .... "	203,566	1 00	203,566	
Excavation, earth, dry .... "	105,000	0 35	36,750	
Range lights, marking piers, &c	....	....	49,150	
				298,067
Damages—				
Land and rights	....	....	52,805	
Water powers	....	....	10,000	
Highway diversion	....	....	5,000	
Highway bridge	....	....	65,000	
				132,805
				1,946,500
Contingencies, engineering, &c	....	....	....	194,650
Total	....	....	....	2,141,150

For analysis and general features refer to page 118 and to estimate plan No. 22.

MOUNTAIN CHUTE REACH, CALUMET CHANNEL.

Mountain Chute Lock to Calumet Lock, Miles 184 to 187.

Surface Elevation 315, Surface below Lock, Elevation 280, Lift 35 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Mountain Chute Lock—				
Excavation, rock, dry.....C. yds.	44,834	1 00	44,834	
Excavation, earth, dry..... "	72,664	0 35	12,534	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, &c.....C. yds.	72,029	7 50	540,218	
Entrance piers, cribwork..... "	82,800	3 50	289,800	
Entrance piers, concrete wall..... "	6,400	7 50	48,000	
Entrance piers, rock fill..... "	63,468	0 50	31,734	
Lock gates..... Tons.	820	120 00	106,800	
Gate operating machines..... Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lighting..	.....	.....	10,000	
Bollards, ladders, life chains, &c.....	.....	.....	10,000	
				1,123,760
Dam and Regulation—				
Dam, rock, loose.....C. yds.	159,432	0 50	79,716	
Dam, earth face..... "	39,858	0 25	19,929	
Stop-log sluices.....	.....	.....	90,426	
Operating machines..... Each.	3	700 00	2,100	
				192,171
Channel—				
Excavation, rock, dry.....C. yds.	115,205	1 00	115,205	
Excavation, earth, dry..... "	107,825	0 35	37,739	
Range lights, marking piers, &c.....	.....	.....	18,750	
				171,694
Damages—				
Land and rights.....	.....	.....	6,000	
				6,000
				1,493,600
Contingencies, engineering, &c.....	.....	.....	.....	149,360
Total.....	.....	.....	.....	1,642,960

For analysis and general features refer to page 118 and to estimate plan No. 22.

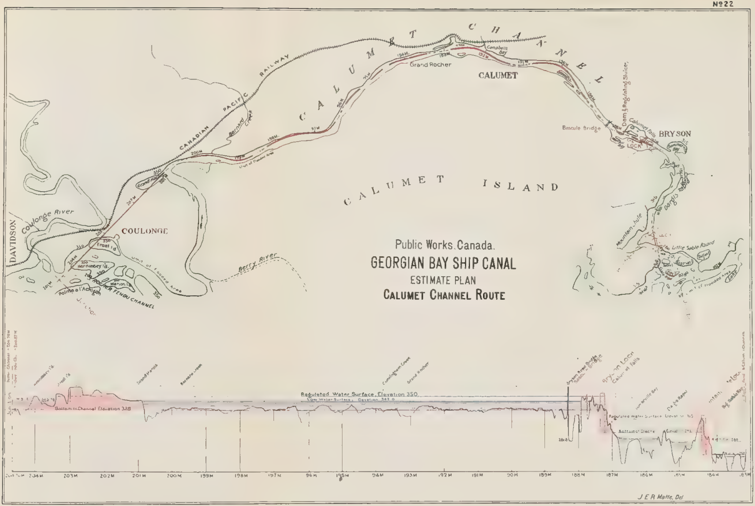
COULONGE LAKE REACH, CALUMET CHANNEL.

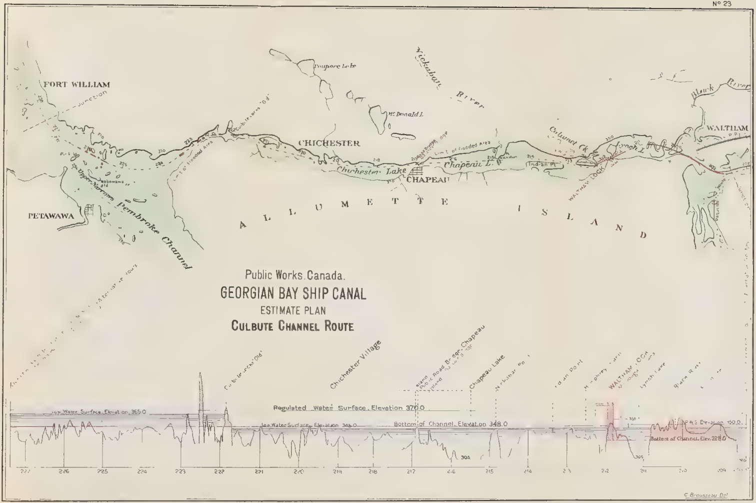
Calumet Lock to Paquette Rapids, Miles 187 to 212—(Mile 209 Main Line).

Surface Elevation 350, Surface below Lock, Elevation 315, Lift 35 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
Calumet Lock—					
Excavation, rock, dry	C. yds.	81,026	1 00	81,026	
Unwatering pit				10,000	
Concrete, lock walls, &c	C. yds.	45,593	7 50	341,948	
Entrance piers, cribwork	"	16,955	3 50	59,343	
Entrance piers, concrete wall	"	6,200	7 50	46,500	
Entrance piers, rock fill (back of wall)	"	37,200	0 50	18,600	
Lock gates	Tons.	820	120 00	106,800	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lighting				10,000	
Bollards, ladders, life chains, &c				10,000	
					704,057
Dam and Regulation—					
Dam, rock, loose	C. yds.	40,718	0 50	20,359	
Dam, earth, face	"	10,180	0 50	5,090	
Dam, borrow pit, rock	"	18,288	1 00	18,288	
Stop-log sluices				116,006	
Operating machines	Each.	4	700 00	2,800	
					162,543
Channel—					
Excavation, rock, wet	C. yds.	6,356	3 00	19,068	
Excavation, rock, dry	"	219,596	1 00	219,596	
Excavation, earth, wet	"	4,926,992	20 and 35	1,128,387	
Excavation, earth, dry	"	3,202,092	25 and 35	823,224	
Bank lining	"	22,000	2 00	44,000	
Range lights, marking piers, &c				59,950	
					2,293,225
Damages—					
Land and rights				14,730	
Highway diversion				5,000	
Highway bridges				75,000	
					94,730
					3,254,500
Contingencies, engineering, &c					325,450
Total					3,578,950

For analysis and general features refer to page 118 and estimate plan No. 22.


Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
CALUMET CHANNEL ROUTE
CALUMET CHANNEL
CANADIAN PACIFIC RAILWAY
CALUMET ISLAND
CALUMET
Grand Rocher
Campbells Bay
BRYSON
Bascule Bridge
Dam & Regulating Sluice
Calumet Falls
LOCK
COULONGE
Coulonge River
DAVIDSON
Berry River
Bernard Creek
Frost Id
Hennessey Id
Marion Id
ROCHER FENDU CHANNEL
Pointe a l'Aichigan
Little Sable Rapid
Limit of Flooded Area
Regulated Water Surface Elevation 350
Low Water Surface Elevation 343.0
Bottom of Channel Elevation 325
Regulated Water Surface Elevation 315
204M
203M
202M
201M
200M
199M
198M
197M
196M
195M
194M
193M
192M
191M
190M
189M
188M
187M
186M
185M
184M
183M
J E R Matte, Dd


FORT WILLIAM
CHICHESTER
CHAPEAU
PETAWAWA
WALTHAM
ALLUMETTE ISLAND
Pembroke Channel
Chichester Lake
Chapeau L.
Indian Pt.
Calumet Ck.
Lynch L.
Black River
McDonald L.
Poupore Lake
Limit of Flooded Area
WALTHAM LOCK
Public Works. Canada.
GEORGIAN BAY SHIP CANAL
ESTIMATE PLAN
CULBUTE CHANNEL ROUTE
Chichester Village
Chapeau Lake
Indian Point
Lynch Lake
Regulated Water Surface, Elevation 370.0
Low Water Surface, Elevation 365.0
Low Water Surface, Elevation 345.0
Bottom of Channel, Elevation 348.0
Bottom of Channel, Elev. 328.0
C. Brousseau Del.

COULONGE LAKE REACH VIA HENNESSEY BAY.

Rocher Fendu Lock No. 2 to Westmeath Lock, Miles 190 to 207—(Main Line Chainage,—Continued.)

Surface Elevation 350, Surface below Lock, Elevation 315, Lift 35 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Rocher Fendu, Lock No. 2—				
Excavation, rock, dry.....C. yds.	137,852	1 00	137,852	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, &c.....C. yds.	41,743	7 50	313,073	
Entrance piers, cribwork..... "	93,114	3 50	325,900	
Entrance piers, concrete wall..... "	7,600	7 50	57,000	
Entrance piers, rock fill..... "	123,600	0 50	61,800	
Lock gates..... Tons.	890	120 00	106,800	
Gate operating machines..... Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lighting.	.....	.....	10,000	
Bollards, ladders, life chains, &c.....	.....	.....	10,000	
				1,052,265
Dam and Regulation—				
Dam, rock, loose.....C. yds.	489,504	0 50	244,752	
Dam, earth face..... "	122,326	0 50	61,163	
Dam, borrow pit, rock..... "	142,100	1 00	142,100	
Stop-log sluices.....	.....	.....	137,009	
Operating machines..... Each.	5	700 00	3,500	
				588,524
Channel—				
Excavation, rock, wet.....C. yds.	273,294	3 00	819,882	
Excavation, rock, dry..... "	792,485	1 00	792,485	
Excavation, earth, wet..... "	2,231,551	20c. and 35	551,463	
Range lights, marking piers, &c.....	.....	.....	35,650	
				2,199,480
Damages—				
Land and rights.....	.....	.....	4,730	
				4,730
				3,845,000
Contingencies, engineering, &c.....	.....	.....	.....	384,500
Total.....	.....	.....	.....	4,229,500

For analysis and general features refer to page 116 and estimate plan No. 11.

ESTIMATE OF PEMBROKE REACH VIA HENNESSEY BAY.

Westmeath Lock to Des Joachims, Miles 207 to 262 (Mile 265 Main Line).

Surface Elevation 370, Surface below Lock, Elevation 350, Lift 20 feet.

Description.	Quantity.	Price.	Cost.	Total.s
		$ cts.	$	$
Westmeath Lock—				
Excavation, rock, dry.................C. yds.	475,371	1 00	475,371	
Excavation, earth, dry.................. "	270,879	0 35	94,808	
Unwatering pit..............................	....	....	10,000	
Concrete, lock walls, &c.................C. yds.	36,400	7 50	272,940	
Entrance piers, cribwork................ "	15,171	3 50	53,100	
Entrance piers, concrete wall............ "	8,000	7 50	60,000	
Entrance piers, rock fill (back of wall)..... "	16,000	0 50	8,000	
Lock gates................................ Tons.	695	120 00	83,400	
Gate operating machines................ Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lighting.	....	....	10,000	
Bollards, ladders, life chains, &c...............	....	....	10,000	
				1,097,459
Dam and Regulation—				
Dam, rock, loose.......................C. yds.	79,800	0 50	39,900	
Dam, earth, face...................... "	43,100	0 25	10,775	
Stop-log sluices.............................	....	....	77,298	
Operating machines..................... Each.	3	700 00	2,100	
				130,073
Channel—				
Excavation, rock, wet..................C. yds.	1,293,555	1 50	1,940,332	
Excavation, rock, wet.................. "	237,000	3 00	711,000	
Excavation, rock, dry.................. "	815,998	1 00	815,998	
Excavation, earth, wet.................. "	133,333	0 35	46,667	
Excavation, earth, dry.................. "	478,564	0 35	167,497	
Bank lining.............................. "	11,000	2 00	22,000	
Range lights, marking piers, &c...............	....	....	74,850	
				3,778,344
Damages—				
Land and rights..............................	....	....	175,285	
Highway bridge..............................	....	....	10,000	
				185,285
				5,191,200
Contingencies, engineering, &c..................	....	....	....	519,120
Total..................................	....	....	....	5,710,320

For analysis and general features refer to page 116 and estimate plan No. 11.

COULONGE LAKE REACH VIA CULBUTE CHANNEL.

Rocher Fendu Lock No. 2 to Waltham Lock, Miles 190 to 212 (Main Line Chainage.—Continued.)

Surface Elevation 360, Surface below Lock, Elevation 315, Lift 35 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Rocher Fendu, Lock No. 2—				
Excavation, rock, dry.....C. yds.	137,852	1 00	137,852	
Unwatering pit.....	.....	.....	10,000	
Concrete, lock walls, &c.....C. yds.	41,743	7 50	313,073	
Entrance piers, cribwork..... "	93,114	3 50	325,900	
Entrance piers, concrete wall..... "	7,600	7 50	57,000	
Entrance piers, rock fill..... "	123,600	0 50	61,880	
Lock gates..... Tons.	890	120 00	106,800	
Gate operating machines..... Each.	8	500 00	4,000	
Filling and emptying valves and machinery. "	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lighting.	.....	.....	10,000	
Bollards, ladders, life chains, &c.....	.....	.....	10,000	
				1,052,265
Dam and Regulation—				
Dam, rock, loose.....C. yds.	489,504	0 50	244,752	
Dam, earth, face..... "	122,326	0 50	61,163	
Dam, borrow pit, rock..... "	142,100	1 00	142,100	
Stop-log sluices.....	.....	.....	137,009	
Operating machines..... Each.	5	700 00	3,500	
				588,524
Channel—				
Excavation, rock, wet.....C. yds.	380,648	3 00	1,141,944	
Excavation, rock, dry..... "	792,485	1 00	792,485	
Excavation, earth, wet..... "	5,134,481	20c., and 35	1,132,041	
Bank lining..... "	20,000	2 00	40,000	
Range lights, marking piers, &c.....	.....	.....	43,050	
				3,149,520
Damages—				
Land and rights.....	.....	.....	4,730	
Black River diversion.....	.....	.....	20,000	
				24,730
				4,815,000
Contingencies, engineering, &c.....	.....	.....	.....	481,500
Total.....	.....	.....	.....	5,296,500

For analysis and general features refer to page 119 and estimate plan No. 23.

PEMBROKE REACH VIA CULBUTE CHANNEL.

Waltham Lock to Des Joachims, Miles 212 to 255—(Mile 265 Main Line).

Surface Elevation 350, Surface below Lock, Elevation 370, Lift 20 feet.

Description.	Quantity.	Price.	Cost.	Totals.
		$ cts.	$	$
Waltham Lock—				
Excavation, rock, dry.......C. yds.	71,380	1 00	71,380	
Unwatering pit..........	....	....	10,000	
Concrete, lock walls, &c.......C. yds.	51,118	7 50	383,385	
Entrance piers, cribwork.......“	46,241	3 50	161,844	
Entrance piers, concrete wall.......“	7,260	7 50	54,450	
Entrance piers, rock fill (back of wall).....“	43,560	0 50	21,780	
Lock gates.......Tons.	695	120 00	83,400	
Gate operating machines.......Each.	8	500 00	4,000	
Filling and emptying valves and machinery. “	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights...	....	....	10,000	
Bollards, ladders, life chains, &c.......	....	....	10,000	
				826,079
Dam and Regulation—				
Dam, rock, loose.......C. yds.	265,032	0 50	132,516	
Dam, earth face.......“	48,020	0 50	24,010	
Dam, borrow pit, rock.......“	24,761	1 00	24,761	
Stop-log sluices.......	....	....	89,663	
Operating machines.......Each.	5	700 00	3,500	
				274,450
Channel—				
Excavation, rock, wet.......C. yds.	129,192	3 00	387,576	
Excavation, rock, dry.......“	749,864	1 00	749,864	
Range lights, marking piers, &c.......	....	....	61,200	
				1,198,640
Damages—				
Land and rights.......	....	....	68,750	
Water powers.......	....	....	10,000	
Highway diversion.......	....	....	10,000	
Highway bridge.......	....	....	65,000	
				153,750
				2,453,000
Contingencies, engineering, &c.......	....	....	....	245,300
Total.......	....	....	....	2,698,300

For analysis and general features refer to page 120 and estimate plan No. 23.

MACKEY REACH VIA McCONNELL LAKE.

Des Joachims to Ferris Bay, Miles 265 to 271.

Surface Elevation 410, Surface below Lock, Elevation 370, Lift 40 feet.

Description.		Quantity.	Price.	Cost.	Totals.
			$ cts.	$	$
McConnell Lake Lock—					
Excavation, rock, dry	C. yds.	131,241	1 00	131,241	
Excavation, earth dry	"	475,045	0 35	166,266	
Unwatering pit				10,000	
Concrete, lock walls, &c	C. yds.	99,244	7 50	744,300	
Entrance piers, cribwork	"	61,429	3 50	215,002	
Entrance piers, concrete wall	"	7,400	7 50	55,500	
Entrance piers, rock fill (back of wall)	"	44,400	0 50	22,200	
Lock gates	Tons.	965	120 00	115,800	
Gate operating machines	Each.	8	500 00	4,000	
Filling and emptying valves and machinery.	"	4	3,960 00	15,840	
Gate and valve motors, storage batteries, lights				10,000	
Bollards, ladders, life chains, &c				10,000	
					1,500,179
Dam and Regulation—					
Dam, rock, loose	C. yds.	193,382	0 50	96,691	
Dam, earth face	"	48,346	25c., 50	17,375	
Dam, borrow pit rock	"	42,304	1 00	42,304	
Stop-log sluices				52,184	
Operating machines	Each.	2	700 00	1,400	
					209,954
Channel—					
Excavation, rock, dry	C. yds.	1,297,165	1 00	1,297,165	
Excavation, earth, dry	"	183,126	0 35	64,094	
Range lights, marking piers, &c				14,750	
					1,376,009
Damages—					
Land and rights				5,000	
Highway bridge				10,000	
					15,000
					3,101,200
Contingencies, engineering, &c					310,120
Total					3,411,320

For analysis and general features refer to page 118.

SUMMARY OF ESTIMATE COST, ALTERNATIVES ROUTES.

BACK RIVER SECTION.

	Lock.	Dam.	Regulation.	Channel.	Damages.	Totals.	Total Cost with Contingencies, Engineering, &c.
	$	$	$	$	$	$	$
Bout de L'Ile reach	....	....	....	1,430,700	120,000	1,550,700	
Prairies reach	812,900	52,200	62,000	2,765,400	454,600	4,147,100	
Recollet reach	1,245,900	....	367,900	5,649,500	513,300	7,776,600	
	2,058,800	52,200	429,900	9,845,600	1,087,900	13,474,400	14,821,840

CALUMET CHANNEL SECTION.

	Lock.	Dam.	Regulation.	Channel.	Damages.	Totals.	Total Cost with Contingencies, Engineering, &c.
Portage du Fort reach	919,400	471,000	125,200	298,100	132,800	1,946,500	
Mountain reach	1,123,800	99,600	92,500	171,700	6,000	1,493,600	
Coulonge reach	704,100	43,700	118,800	1,470,000	94,700	2,431,300	
	2,747,300	614,300	336,500	1,939,800	233,500	5,871,400	6,458,540

HENNESSEY BAY SECTION.

	Lock.	Dam.	Regulation.	Channel.	Damages.	Totals.	Total Cost with Contingencies, Engineering, &c.
Coulonge reach	1,052,300	448,000	140,500	2,199,500	4,700	3,845,000	
Pembroke reach	1,097,500	50,700	79,400	3,778,300	185,300	5,191,200	
	2,149,800	498,700	219,900	5,977,800	190,000	9,036,200	9,939,820

CULBUTE CHANNEL SECTION.

	Lock.	Dam.	Regulation.	Channel.	Damages.	Totals.	Total Cost with Contingencies, Engineering, &c.
Coulonge reach	1,052,300	488,000	140,500	3,149,500	24,700	4,815,000	
Pembroke reach	826,100	181,300	93,200	1,198,600	153,800	2,453,000	
	1,878,400	629,300	233,700	4,348,100	178,500	7,268,000	7,994,800

McCONNELL LAKE SECTION.

	Lock.	Dam.	Regulation.	Channel.	Damages.	Totals.	Total Cost with Contingencies, Engineering, &c.
Mackey reach	1,500,200	156,400	53,600	1,376,000	15,000	3,101,200	3,411,320

MAINTENANCE.

The canalization of the French, Mattawa and Ottawa rivers on the scale proposed, would probably form the largest navigation system of the kind ever attempted, and the question of the cost of annual maintenance is a feature which has to be considered very carefully.

Maintenance may be analysed under six different heads:—

1. Cost of engineering staff.
2. Cost of operating staff at locks.
3. Cost of attendance staff for channel lights, bridges, sluice-ways, &c.
4. Cost of repair staff, crews for repair outfits, &c.
5. Approximate cost, attendance storage regulation.
6. Approximate cost of materials required annually for repairs, renewal of machinery, &c.

1. Cost of engineering staff.—The duties of the main engineering staff of the waterway would be to keep the canals in repair and superintend necessary construction due to maintenance of channels, locks, operating machinery, lights, &c.

The staff would consist of a chief engineer, who would at the same time be superintendent of operation, assistant engineer, technical draftsmen, (design, mechanical and electrical), one chief electrician, one master mechanic, and necessary clerical help.

The pay for the above may be approximated as follows:—

Chief engineer and superintendent of waterways..	$ 8,000	per year	× 1 =	$8,000
Chief assistant engineer	5,000	"	× 1 =	5,000
Assistant engineers, each..	3,000	"	× 2 =	6,000
Chief electrician..	2,400	"	× 1 =	2,400
Master mechanic..	2,400	"	× 1 =	2,400
Technical draftsmen, each..	1,800	"	× 2 =	3,600
Clerk of works..	1,500	"	× 1 =	1,500
Ordinary draftsmen and clerical attendance..				5,000
Travelling expenses, disbursements, &c..				5,000
Total..				$38,900

2. Cost of operating staff at locks: There will be required at each single lock, one lockmaster, one electrician, one assistant electrician, four motormen—two for each shift—one electric lineman, and eight linemen—four each shift.

For each flight of two locks; one lockmaster, one electrician, one assistant electrician, six motormen—three each shift. one electric lineman, and ten boat linemen—five each shift.

The following table will therefore give the required strength of staff for each step in the canal profile.

In case of two single locks being close together, electricians are supposed to attend to both.

Lock Location.	Lockmaster.	Electrician.	Assistant Electrician.	Lock Motormen.	Electric Linemen.	Boat Linemen.
Montreal	1	1	1	4	1	8
Verdun	1	....	....	4	1	8
Ste. Anne	1	1	1	4	1	8
Pointe Fortune	1	1	1	4	1	8
Hawkesburry	1	1	1	4	1	8
Hull No. 1	1	1	1	4	1	8
Hull No. 2	1	....	....	4	1	8
Chats	1	1	1	4	1	8
Chenaux	1	1	1	4	1	8
Rocher Fendu No. 1	1	1	1	4	1	8
Rocher Fendu No. 2	1	....	....	4	1	8
Paquette	1	1	1	4	1	8
DesJoachims	1	1	1	4	1	8
Rocher Capitaine	1	1	1	4	1	8
Deux Rivieres	1	1	4	6	1	10
Mattawa	1	1	1	4	1	8
Plain Chant	1	1	1	4	1	8
Les Epines	1	1	1	4	1	8
Lower Paresseux	1	1	1	4	1	8
Upper Paresseux	1	1	1	6	1	10
North Bay	1	1	1	6	1	10
Chaudiere	1	1	1	4	1	8
Five Mile Rapid	1	1	1	4	1	8
Dalles	1	1	1	4	1	8
	24	21	21	102	24	198

In addition to the above there will be required three division superintendents for operation with a staff of clerks.

The expenditure may be approximated as follows:—

Division Superintendents,	$3,000 per year,	× 3 =	$	9,000
Staff of clerks for the three divisions				9,000
Lockmaster (single lock),	$1,000 per year,	× 21 =		21,000
Lockmaster (flight locks),	1,200 per year,	× 3 =		3,600
Electrician	900 per year,	× 21 =		18,900
Asst. Electrician	700 per year,	× 21 =		14,700
Motormen	400 per season,	× 102 =		40,800
Electrical linemen	350 per season,	× 24 =		9,600
Boat linemen	350 per season,			69,300
Extra help..				2,000
	Total		$	197,900

3rd.—Cost of staff for attendance to channel lights, bridges, sluice-ways, telephone lines, etc. At each of the sets of regulating sluice-ways, attendants will be required for the constant handling of the sluice gates to maintain the required elevation of the pools they control.

The bascule bridges will require either one or two bridge motormen, according to the bridges being single or double leaf structures, two shifts to be provided.

Telephone attendance may be assumed to be done by the regular staff at each of the lock, bridge and sluice stations.

For the up-keep of the lighting system other than at the locks, it is assumed that a launch patrol system covering the different reaches would be the most convenient arrangement, so as to cover the stretch assigned to it, daily for inspection and such repairs as would be found necessary.

The initial cost of the launches may be considered as included under lighting in the main estimates , a sufficient amount being allowed therein by an excess percentage for contingencies, equipment, etc.

The expenditure in connection with the above may be detailed as follows:—

Sluice attendants, ...	$600 per year,	× 40 =	$24,000
Bridge motormen	600 2 shifts,	× 44 =	26,400
24 launches, 50 men, 400 per season, including lighthouse tenders			20,000
Total			$70,400

4th.—Cost of repair staff, crews for repair outfits, etc.

It may be assumed that floating plants with their crews, for all repair work to gates, lock machinery, bridges, sluice-ways, etc., would be located at Montreal, Ottawa, Pembroke, Mattawa and North Bay.

This will make five plants the cost of which may be considered to come in the general estimates under the percentage increase for contingencies.

The expenditure for wages for one plant may be detailed as follows:—

Gate lifter, one man in charge, per year .. ..$	500
Tug and crew, $20 for 210 days	4,200
Floating shop and crew, $15 for 210 days	3,150
Tug and crew	4,200
Supply boat and crew	4,200
Dredge, scows, tug crews, $50 for 210 days	10,500
Diving outfit and helpers	2,500
Carpenter oufit	2,500
Painting outfit	2,500
Pumping outfit	3,000
Total .. ..$	37,250

Five outfits at $37,250 = $186,250.

5th.—Cost of attendance, storage regulation, telephone lines, repairs, &c.

For the storage reservoir system about 200 men for sluice operation, telephone lines, &c., will be required to remain resident at the various dam sites. This will require the following approximate expenditure in wages:—

100 men at $500 per year..	$ 50,000
Extra help during high water period..	10,000
Annual repairs to dams, &c..	30,000
Total..	$ 90,000

6th.—Approximate cost of materials, supplies, power, &c., under this head would be, cost of production of power, materials required for repairs, renewal of machinery, supplies for lights and boats, &c. Some of these items can be analysed and a fair approximate cost arrived at, but others can only be assumed.

In an analysis of cost of maintenance prepared for the Sault Ste. Marie, the Soulanges and the Welland canals, which is given for different years, it will be remarked that repairs have generally approximated the amount paid in wages to the staff employed.

SAULT STE. MARIE CANAL.

TABLE SHOWING DETAILED COST OF MAINTENANCE.

Year.	Staff employed throughout the Year.	Motormen.	Staff during Navigation.	Linemen.	Total number of men employed.	Wages of Staff.	Expenses of Staff.	Repairs.	Total Cost of Maintenance.
						$ cts.	$ cts.	$ cts.	$ cts.
1901-02	5	8	11	12	36	16,427 47	1,006 53	14,839 71	32,273 71
1902-03	5	11	13	11	40	16,609 94	1,000 08	10,855 70	28,465 72
1903-04	5	9	14	7	35	15,169 57	793 93	9,491 44	25,454 94
1904-05	5	8	14	11	38	16,732 54	981 41	14,776 33	32,490 28
1905-06	6	9	17	13	45	15,835 49	1,505 22	20,086 15	37,426 86
Average	5	9	14	11	39	16,155 00	1,057 43	14,009 86	31,222 30

NOTE.—Between extreme ends of the entrance piers, 5,967 feet. One lock.

SOULANGES CANAL.

TABLE SHOWING COST OF MAINTENANCE.

Year.	Staff employed throughout the Year.	Motormen.	Guard Gatemen, Bridgemen, &c.	Total Men.	Wages of Men for One Lock.	Wages of Staff.	Staff Expenses.	Repairs.	Total Cost of Maintenance.
					$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
1902-03	3	22	55	80	1,475 14	18,749 93	2,384 84	22,810 89	43,945 66
1903-04	5	21	37	63	1,490 30	20,787 41	6,264 79	26,929 28	53,981 48
1904-05	5	22	62	89	1,540 09	21,675 70	5,463 04	21,174 84	48,313 58
1905-06	5	22	42	69	1,600 71	22,699 11	3,882 11	17,096 33	43,677 55
Average	5	22	49	75	1,526 56	20,978 04	4,498 70	22,002 83	47,479 57

NOTE.—5 locks and 1 guard gate. 7 bridges. Canal 14 miles long.

CORNWALL CANAL.

TABLE SHOWING DETAILED COST OF MAINTENANCE.

Year.	Staff employed throughout the Year.	Lockmen.	Guard Gatemen and Bridgemen.	Total Men Employed.	Wages of men for One Lock.	Wages of Staff.	Staff Expenses and Electric L. & P.	Repairs.	Total Cost of Maintenance.
					$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
1902-03	4	34	9	47	2,351 37	20,019 56	52,255 79	19,205 66	89,334 95
1903-04	2	30	9	46	2,494 74	20,469 90	26,702 54	20,932 55	66,725 19
1904-05	4	29	10	43	2,793 50	23,137 06	48,621 45	28,100 67	99,859 18
1905-06	3	32	8	43	2,824 05	22,339 02	50,395 45	31,893 13	104,627 60
Average	3	31	9	45	2,615 91	21,491 39	44,493 81	25,033 00	90,136 73

NOTE.—Length, 11·5 miles. 6 locks. 2 bridges and 1 guard gate.

WELLAND CANAL.

TABLE SHOWING DETAILED COST OF MAINTENANCE.

Year.	Staff employed throughout the Year.	Lockmen.	Guard Gate-men, Bridge-men, &c.	Total Men.	Wages of Men for One Lock.	Wages of Staff.	Staff Expenses.	Repairs.	Total Cost of Maintenance.
					$ cts.	$ cts.	$ cts.	$ cts.	$ cts.
1901–02...	8	113	215	336	1,608.75	73,693 99	15,582 84	69,219 18	158,496 01
1902–03...	9	113	229	351	1,608 77	77,822 83	15,336 03	72,004 59	165,163 45
1903–04...	9	120	272	401	1,616 25	77,761 57	16,472 45	85,717 88	179,951 92
1904–05...	8	113	273	394	1,640 32	79,694 90	17,098 13	111,418 62	208,211 65
1905–06...	10	115	265	390	1,656 90	85,416 82	24,016 23	78,704 93	188,138 08
Average...	9	115	251	374	1,626 19	78,878 02	17,701 13	83,413 04	179,992 22

NOTE.—25 locks. 26·7 miles. 1 guard gate.

In the case under consideration, the total expenditure in connection with operating staff, as prepared in the previous pages would amount to $307,200. Assuming therefore about the same amount for materials, &c., would seem ample to cover this part of the maintenance, and $300,000 is added to the figures relating to the other items.

SUMMARY.

Cost of engineering staff..	$ 38,900
Cost of operation staff at locks..	197,900
Cost of staff, lights, sluice and bridge tenders, &c.. ..	70,400
Cost of crews for repair outfits, &c..	186,250
Storage reservoirs, wages and up-keep..	90,000
Materials for repairs, machinery, &c..	300,000

Operation and repairs per year would then be as follows:—

Operation canal proper..	$ 307,200
Operation reservoir system..	90,000
Repair outfits and materials, &c..	486,250
Total..	$883,450, say $900,000

BARGE CANAL VS. SHIP CANAL.

During the course of the survey, the suggestion has often been made that a 14 foot waterway or barge canal would be all that would be necessary to meet the requirements of commerce and that it would be much cheaper than a 22 foot canal; therefore it could be undertaken much more easily at the present time, without taxing the resources of the country to a perceptible degree. If Canada did not possess already a first class 14 foot waterway from the Great Lakes to the Seaboard, and did not feel, so evidently, the need of something better, then a barge canal through the Ottawa, at relatively low cost, should naturally be given the most careful consideration.

In the light, however, of actual experience on the St. Lawrence canals, it is problematical whether a similar canalization of the French and Ottawa rivers would meet with greater success in diverting the commerce of the Great Lakes, which should seek the Canadian channels.

It is recognized that the bulk of the traffic on the Great Lakes is now carried by boats drawing from 15 to 20 feet of water when loaded, and the most successful carriers are those from 5,000 to 12,000 or 13,000 tons capacity.

A waterway that will be able to accomodate the present lake fleet, passing the largest lake freighters when necessary, rather than only accommodate a special class of boats of limited size, which would have to be built, is bound to attract immediately the attention of shippers. Moreover, when this waterway can show from the head of the Great Lakes to the nearest Ocean Port, a through route shorter by nearly 300 miles than any other existing or possible route, thus assuring faster trips, quicker and larger returns, and lower through rates, it is bound, in my opinion, not only to attract attention but to secure trade.

In such a matter of truly national importance the difference in cost of thirty to forty million dollars, for a barge canal as compared with, say, 100 millions for a ship canal should not be a ruling factor. The benefits to be derived by the expenditure of the smaller amount on the shallow draft canal are very doubtful, and, in my mind, under the circumstances could hardly be justified, while the larger project seems to offer reasonable chances of success and provide for future requirements. This should be the deciding factor, if the cost can be borne by the country.

I must therefore record my opinion, in favour of the 22 foot waterway. Any money proposed to be applied on a barge canal would give better results if expended on railway lines or in improving the present St. Lawrence canals. The waterway which must meet modern conditions must also be designed for future needs and the various aspects of the conditions governing the probable requirements may be briefly reviewed.

At both ends of the proposed Georgian Bay Ship waterway are two different systems of water transportation, which commerce demands should be united in the most efficient manner by both rail and water transportation.

At the eastern end, is ocean navigation with its steamers of ever increasing size and draft, relatively difficult of handling through restricted channels and in berthing, requiring at present channels 30 feet deep and over and five to six hundred feet wide.

At the othe r end, on our large inland seas, there has been developed a special type of vessels of very large dimensions, limited in draft to 20 or 21 feet, extremely easy of handling around sharp bends and in narrow channels, quick to obey the steering gear, but of such construction that they cannot probably weather the storms of the ocean. They are well fitted for inland navigation and coast trade.

In connecting these systems of navigation, it seems reasonable that the channels uniting them should be of such size and depth that they will at least allow the large type of freighters which have developed the cheapest inland transportation in the world, to reach seagoing vessels at the nearest Ocean Port without breaking bulk and in the shortest time possible. At the present time, when the paths of commerce on the Great Lakes have already a tendency to be diverted from what seems their natural channels, any connecting link of a shallower depth is practically certain to be unsuccessful. If it was a matter of extending an established system of river navigation, or connecting two systems of canalized rivers of fixed shallow depth, there would be no object in going beyond that depth for the proposed improvement. This would be governed by the fixed conditions on a part of the system already in existence. For instance, after the building of the Georgian Bay ship waterway, one of the branches which will probably have to be considered, will be the canalization of the upper Ottawa, joining first the Lake Temiscaming waters with the main canal. In such a case, the navigation on the lake will govern the depth to be given to the canalized river.

Viewing the question in all its aspects it is felt that the waterway, if undertaken, should be built on the broadest lines possible.

In a growing country like this, with its vast possibilities, great wheat, mineral and forest lands, whose territory extends from the Atlantic to the Pacific, having on its southern boundary the most extensive system of inland waterways in the world, there is no doubt, that the future volume of its trade and transportation will be beyond all our expectations.

In the United States today, it is found that the domestic commerce is very much larger than the foreign commerce, due in large part, according to the most eminent economists, to the Great Lakes which have rendered this development possible. With the improvements of harbours and channels, the lake transportation is expanding rapidly and Canada should control and direct its proper share.

The Great Lakes which represent about 1,000 miles of navigable length are connected with the sea by the St. Lawrence river, a waterway with a depth of 14 feet being available from Lake Ontario to Montreal. Below Montreal a channel sufficiently deep for ocean vessels exists, and this is being deepened and widened to meet the increasing size and draft of modern steamers.

The St. Lawrence canals have not been successful in diverting a fair share of the lake transportation. Modern lake freighters, which have contributed in giving the cheapest transportation rates in the world on the different lakes cannot, on account of their size, use the present canals. A special type of boat had to be developed and since the 14 foot canals were completed, comparatively few vessels of the required type have been built.

When the present St. Lawrence Canal system was completed very few harbours on the lakes had more than 12 or 14 feet of water and such enormous freighters as now exist were not contemplated. The harbours have been deepened since to keep pace with the development of cheap transportation, but the chain of canals once cast, could not be enlarged so easily, as their deepening involves the reconstruction of very expensive structures, which has to be done without interfering with the existing navigation, meaning practically, in most cases, the cutting of new canals and the erecting of new structures.

At present all the connecting channels on the lakes are from 19 to 21 feet in depth, at low water stage, and a great many harbours will accommodate vessels of 20 feet draft. A decided movement in the deepening of harbours and channels to a depth of 12 feet, by the United States government commenced in the seventies. In the eighties, the tendency was to secure 16 feet, and the policy of securing 21 feet was carried out in the next decade.

Since then the size of vessels has increased gradually and now the commerce of the Great Lakes is carried in ships drawing from 15 to 20 feet of water.

No doubt, in the future, the Canadian government will be obliged to increase the dimensions of the St. Lawrence canals. But this should not be set in opposition to the Ottawa river route, which is the most direct and quickest possible waterway from the northwest to a sea port. Only that route, in my opinion, can ever successfully compete with the routes which the United States authorities are trying to develop, and keep the transport of our trade within Canadian territory. But it must be made of such depth and dimensions that it will fully meet the requirements of the lake commerce, or otherwise it should not be undertaken.

Undoubtedly, in the near future, the growth of our trâde will be such that all transportation routes will be taxed to their utmost.

The Georgian Bay ship canal, if built, will occupy a privileged geographical situation over all other arteries of commerce leading to an ocean port. The reduction in time of transit will allow vessels to make more trips during the season. which will have a tendency to reduce the rates from Fort William to Montreal. Its northern position will give great advantage for the transport of perishable goods. Its course is far from international boundary lines and no international waters are involved, it being fed by waters entirely within Canadian territory.

The United States government is now spending $25.000,000 yearly on the improvement of its harbours and inland waterways, and it is proposed to increase this sum to $50,000,000.

European countries have found it to their advantage to provide facilities for both rail and water transportation. England, Germany, France, Belgium and Holland have given much attention to improving their waterways and enlarging their canals. These countries have prospered, owing to the perfection of their roads, to the equipment of their ports and the large number of waterways which they are constantly trying to improve.

The efficiency of the Georgian Bay ship canal, if built, will not only depend on large dimensions and modern equipment, but also on the business organization by which the services of transportation are to be performed.

In the present system of transport on the Great Lakes, there are four different services:—the individual boat-owner, the large companies engaged solely in the carrying trade, the railway companies operating fleets of vessels in conjunction with their railway lines, and the mining and manfacturing companies controlling fleets of vessels of the most modern type.

It is noticeable that in recent years, the individual boat-owner has been driven from the lakes, and now the liveliest form of competition is between the transportation companies and the mining and manufacturing corporations.

When the former demand an unreasonable rate, it is answered by the latter becoming carriers themselves. This has led to gradual concentration, and also to the development of the most economical type of vessels to meet transportation and trade requirements. The possibility, however, of these powerful organizations using the proposed canal will not lead to its control by them, as unlike a railroad it may be used by individuals thus ensuring competition and cheap rates.

The total enrolled tonnage on the Great Lakes is now over 2,000,000 tons; 90 per cent of which is composed of iron ore, lumber, grain and flour. Owing to the great amount of iron ore transported from Lake Superior Ports to the soft coal fields, the East bound traffic is almost five times that of the West bound. (See diagram page 400.)

When Canada has a greater population and is more highly developed, it is probable that the proportions between the East bound and West bound traffic will become more evenly balanced. In the course of time, many sections of the country, will find both railways and waterways necessary for supplying adequately and economically the transportation service required to meet business conditions.

Reverting to the question of barge canal against ship canal, the remarks made by the United States Board of Engineers in this connection in their report on the proposed 14-foot waterway, from Lockport, Ill., to St. Louis, Mo., by way of the Des Plaines and Illinois rivers and the Mississippi, entirely confirm the views expressed in the preceding pages. They state that the use of barges is on the decline and very few, if any, new ones are being built for the lake trade.

The part of their report referirng to this is of great interest and may be quoted here at length:—

"The tendency of modern shipbuilding is to increase the size of vessels when the depth of water and the volume of trade permit it. As the old fleet wears out and is replaced by new vessels, it is probable that the proportion of trade carried on the lighter draft will become less than that just given. From which it appears that a draft of 14 feet will not accommodate the most important lake traffic.

As this depth is not sufficient to accommodate lake traffic and is more than is needed for existing river traffic (Mississippi river) the proposed 14-foot waterway, if fully utilized, must be adapted to a traffic different from either. The fleet which is to use it, is not now in existence. It seems probable that when erected it will consist to some extent of steel barges built to draw 12 or 13 feet when loaded and towed in groups by powerful tow-boats or tugs, after the method followed on the Mississippi river, modified to suit the greater depth, narrower channels and gentler currents. The tows will probably consist of fewer barges and the barges will probably be of a different model, being longer and deeper for the same beam. Omitting the coal tows from the Ohio river as inapplicable in any event to the proposed waterway, the most important barge traffic so far developed on the Mississippi river was that of the Mississippi Valley Transportation Company, of St. Louis, carrying freight, principally grain, from St. Louis to New Orleans. The fleet of this company in 1889 consisted of 13 tow boats and 102 freight besides 10 fuel barges. The standard barge was 225 feet long with 36 feet beam, and carried 1,400 tons of grain when loaded to a draft of 8 feet, 8 inches, which was the maximum safe draft. A tow consisted of five to seven of these barges, two or three abreast, the others in tandem. . . . . A maximum tow carrying 9,800 tons would cover an area of about 675 by 108 feet. The largest amount of business which the Company did in any one year was in 1889, when it moved 549,464 tons of freight. From that time the business declined and the managers soon decided that they could not compete with the railroads which were being developed rapidly.

The building of new barges was stopped in 1893, and from that time forward the fleet was reduced whenever a favourable opportunity for selling a portion of it arose. In November, 1904, the number of tow boats having been reduced to three and that of the barges to thirty-two, the entire fleet was sold to the Monongahela River Consolidated Coal and Coke Company, of Pittsburg, and the St. Louis company went out of business. It is understood that the purchasers will use some of the vessels for such grain business as may offer at St. Louis, and will transfer the remainder to the Ohio river for the transportation of coal, but it may be said that barge traffic, except for coal, has practically disappeared from the Mississippi river. Barges are still used in local trade for transporting stone, sand, and lumber, one or two barges of moderate size constituting a tow, but the great through-lines for the transportation of large quantities of freight between important terminals, no longer exist.

Turning to the Great Lakes, it is found that the use of barges there also is on the decline. Of the freight, which passed through the locks of the Sault Ste. Marie, in the years from 1888 to 1899, inclusive. nearly one-third was carried in barges, the percentage varying in different years from 26 to 33. In the year

1904, only 18 per cent was carried in barges. Of the lake traffic of Duluth and Superior in the years 1895 to 1899, inclusive, nearly one-quarter was carried in barges, the percentages varying in different years from 20 to 26. In the year 1904, only 13 per cent was carried in barges.

The foregoing are the most reliable statistics of traffic kept anywhere on the Great Lakes. Very few, if any, new barges are being built for the lake traffic, all new vessels, as a rule, being made self-propelling."

The above shows clearly the decline of barge traffic on the Great Lakes as well as on the Mississipi and further comments on this question are unnecessary.

As to the relation between cost and probable benefits to be derived from the construction of the waterway, sufficient has been said to show the importance of providing channels of such depth and width which will meet the requirements of modern transportation, and insure returns to the general public commensurate with the amount of money invested, at least, in indirect results, if not by revenue from tolls levied on tonnage.

Heavy tolls, high enough to cover cost of maintenance, interest on capital, sinking fund and profits, might have a tendency to defeat the object in view in building the canal, and it might be necessary to make it a free waterway or impose such slight tolls that with the revenue derived from the leases of water-powers, the cost of maintenance at least would be covered. It would be very hard to establish the true relation between cost and probable benefits, either direct or indirect of such an undertaking and any attempt at calculations in this regard would have to be based on assumptions.

Perhaps, a safer guide than expert reports and figures in this connection, is the feeling which pervades the general public and particularly the transportation and business men, that the canalization of this route for large navigation is of primary importance to the interests of this country.

As to the advisability of expending such a large sum for its construction, and whether the country could at the present time afford this expenditure, is a question on which, no doubt, differences of opinion will arise, but which I am not called upon to discuss.

The same remark applies to the question of rates and the saving which might be effected should the proposed waterway be built. This is a matter of discussion quite outside the limits of this report, and only a few general remarks are offered for consideration.

It is well known now, that transportation by water on a first-class shipway is not only cheaper than by rail, but often much quicker.

It is recognized in the United States that the average movement of freight by rail is only twenty-five miles per day, or about one mile per hour, including of course, all delays at stations and at terminals, where cars are frequently side-tracked for several days. Any one conversant with the movement of freight on the Great Lakes can see that the average there is considerably above this figure.

Mr. Joseph E. Ransdell, President of the National Rivers and Harbours Congress, in the Annals of the American Academy of Political and Social Science states:

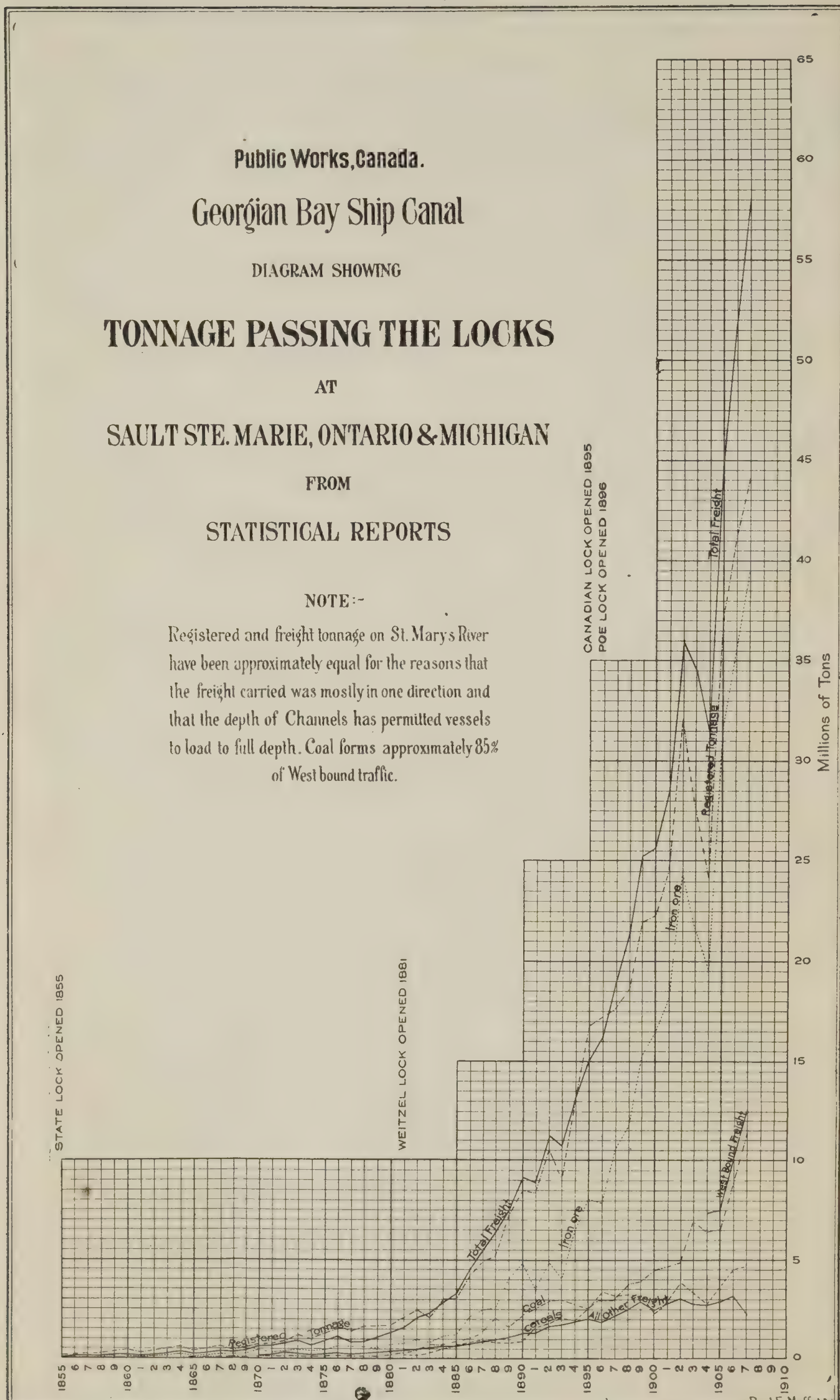
'As to the relative cost by the two methods, there can be no difference of opinion. The Interstate Commerce Commission reported that the average cost of moving freight by rail in 1906 was 7·48 mills per ton per mile. The statistical report on the lake commerce for 1906 by Colonel Davis, U.S.E.C., shows it cost to move over 51,000,000 tons through the Sault Ste. Marie canal last year .84 mills of 1 mill per ton per mile or one-ninth of the average rail rate . . . .

From the best information I can get after a careful study of the subject, I am convinced that waterway transportation in this country, under favourable conditions, costs only about one-sixth as much as the average cost by rail. The

above remarks apply to the lakes and rivers and furnish unanswerable arguments for their improvement.'

He further states that practically all expenditures on waterways have been profitable investments. They have returned in reduced freight rates to the United States people from 100 to 200 per cent yearly.

There is no doubt that money expended at present, on well advised improvements of harbours and rivers is a wise expenditure which benefits the entire country.


Public Works, Canada.
Georgian Bay Ship Canal
DIAGRAM SHOWING
TONNAGE PASSING THE LOCKS
AT
SAULT STE. MARIE, ONTARIO & MICHIGAN
FROM
STATISTICAL REPORTS
NOTE:-
Registered and freight tonnage on St. Marys River have been approximately equal for the reasons that the freight carried was mostly in one direction and that the depth of Channels has permitted vessels to load to full depth. Coal forms approximately 85% of West bound traffic.
STATE LOCK OPENED 1855
WEITZEL LOCK OPENED 1881
CANADIAN LOCK OPENED 1895
POE LOCK OPENED 1896
Total Freight
Registered Tonnage
Iron ore
West Bound Freight
Coal
Cereals
All Other Freight
Millions of Tons
Paul E. Moffet, Del.

CONCLUSIONS AND ACKNOWLEDGMENTS.

The main deductions resulting from the different engineering questions treated in the preceding pages are briefly stated in the letter of transmission given at the beginning of this report, and need not be repeated here.

Before closing, however, I desire to express to the government, and to the high officers of the department, my earnest appreciation of the confidence reposed in me, and in the principal engineers, Messrs. C. R. Coutlee and S. J. Chapleau.

The cordial good will of the departmental staff, in facilitating a most arduous task, is highly appreciated, and my thanks are due especially to the chief engineer, secretary and accountant branches.

The universal courtesies extended to the executive officers of the survey by all engineers in the government service both in Canada and the United States, or in private practice, and other persons with whom it has been our privilege to consult and to whom we are indebted for much valuable information, are gratefully acknowledged.

To all the members of the survey and office staffs, I desire to express my most sincere thanks, for their hearty willingness, and full appreciation of the importance of the work, and particularly to Messrs. Coutlee and Chapleau, to whom I feel under obligation for their cordial co-operation, untiring energy and professional ability.

As secretary of the board at head-quarters during the progress of the survey and later in the arrangement of the final data, Mr. J. M. Somerville is deserving of special commendation for the careful and efficient manner in which his duties were performed.

A list of the employees appears in the report under the heading of 'Survey,' and they all deserve favourable mention for the faithfulness with which the different duties assigned to them have been fulfilled.

Some papers giving additional information in relation to the proposed waterway are herewith annexed as appendixes. The maps published, on account of their small scale, do not contain all the information collected, and reference is made to the detail maps to a scale of 400 feet to 1 inch, filed in the offices of the survey, where they may be seen on application.

Valuable information has also been compiled by Mr. A. T. Genest, C.E., on the canals of the world, which it is found impossible to publish in this report, and which has been filed with the records of the survey for future reference.

Respectfully submitted,

A. St. LAURENT,
Engineer-in-charge.

APPENDIX A.

SURVEY RULES.

1. All surveys, plans and estimates as directed to be made under the authority of the Honourable the Minister of Public Works, will be executed under the immediate direction and control of the engineer in charge acting for him.

DISTRIBUTION OF WORK.

2. The surveys will be divided into three districts as follows:—

(1) The Nipissing District or District No. 1, will embrace all that portion of the country between Georgian Bay and Des Joachims rapids on the Ottawa river, by way of French river, Lake Nipissing, Trout lake, Talon lake, Mattawa and Ottawa rivers.

(2) The Ottawa District or District No. 2 will embrace all that portion of the Ottawa river between Des Joachims rapids and the city of Ottawa immediately below the Chaudiere falls.

(3) The Montreal District or District No. 3, will embrace all that portion of the Ottawa and St. Lawrence rivers from Ottawa to Montreal; including an investigation of a possible outlet for the canal to the St. Lawrence river by way of the Rivière des Prairies.

3. To each of these divisions a special district engineer will be assigned.

These district engineers will report to, and receive instructions from the chief engineer through the special resident engineer in charge located at Ottawa.

They will have direct charge and control of all sectional engineers in charge of parties under them, and will freely consult with the chief engineer and engineer in charge.

OBJECT OF THE SURVEY.

4. The immediate object of the survey is: that when the notes are reduced and plotted, a location may be projected on the plans, for a ship canal of not less than 22 feet in depth, a profile drawn and a final estimate made of the kind and amount of all material found necessary to be excavated; the kind and character of foundations; the dimensions of all walls, locks, dams and other structures necessary for the complete design; and the delineating and estimating of all extra right of way for the canal zone proper where such is required as well as for spoil banks, and for overflow areas.

RECONNAISSANCE.

5. A careful reconnaissance of all work assigned to him shall be made in advance by each district engineer, or engineer in charge of parties, so as to confine within the limits necessary any surveys, levels, investigations, soundings and borings required for the examination of all possible routes. Careful consideration of the different methods possible to accomplish the desired end must be given in every case; thus saving time, labour and expense, and yet, at the same time, obtaining all needed information and data.

NOTES AND RECORDS.

6. All the notes and records of every party must be full and complete, and must be clearly and distinctly written, not only with a view to their immediate use; but for their preservation for future service.

7. They must be so full, clear and distinct that they can be quickly and intelligently interpreted and plotted by others who did not make them, and who may be unfamiliar with the section surveyed.

8. Each day's notes must be headed with a brief description of the location of the survey, with the day of the week, day of the month, and the year, the name of the observer or recorder, the observer being the man who actually runs the instrument.

On the following pages of the day's work the date only and after it the word 'continued' must be written. In the back or front of each note book an index of the notes found in that book must be recorded, a key to any abbreviations used, and a list of names of the parties and their respective positions.

On the outside cover of the book must be clearly and neatly written which section and district of the survey it embraces.

9. No record when once made shall be erased. When an erroneous note is recorded, cancel by drawing a line through the figures and rewriting correctly.

10. All computations must be checked, and when checked a check mark thus √ placed after them. On each page of each note book must be written the initials of the persons who made the computations and those who checked the same.

11. All parties shall occupy themselves on days unfit for field work in the computation and plotting of such notes as have not been kept up with the field work. It is well understood that all assistants, rodmen and chainmen when requested to do work on the books, or on the plans at night, in order to keep up with the field work, shall cheerfully do so; the relatively high wages paid for these positions being given with this end in view.

TOPOGRAPHY.

12. The topographic detail will be based on continuous transit and level lines, offsets or secondary circuit transit and level lines run when so required to obtain the necessary data.

Topography will be taken with the view of correctly plotting contours for 5-foot intervals throughout each investigated route where excavation or construction work is likely to be done, and to embrace localities that are likely to be flooded by the raising of the water level in rivers, lakes, &c., and within such limits as are deemed necessary by the district engineer.

13. In addition to the contour lines to be taken, all buildings, or timber lands, or roads, bridges, culverts, railways, fences, streams, outcrops of rock and the kind, &c., within the limits of the survey must be located and defined, and the elevations of the base of different structures, &c., carefully noted.

Property lines with the names of the owners, should also be given, except in the case of small lots in towns or villages where this may be obtained later.

14. When structures are along the line of the proposed canal, details of these structures should be given and the character of any bridges or buildings explained.

15. The width, depth and cross sections of streams crossed by individual routes must be investigated for high, medium and low stages of their flow. Any information regarding extreme high water marks of flood heights obtained along the line of the survey, shall be noted together with the name and address of the informant, the elevation of the water, the date and year at which it occurred and all circumstances connected with the same; whether due to ordinary or extraordinary rains, melting snows, ice gorges, dams, &c.

TRANSIT WORK.

16. A transit party will under general conditions consist of one assistant engineer, one leveller, one rodman, two chainmen, two or more labourers, boats or teams as required.

17. The main object of the transit traverse lines will be to serve as base lines for all subsequent investigations, topography, level lines, soundings, borings, &c.

Oak hubs 2 by 2 inches by 12 inches long will be driven flush with the ground at all transit stations, tacked, centered and with a guard stake driven at the side; preferably at some convenient fixed distance from the hub. Guard stakes will be of pine or oak 2 by 2 inches by 18 inches long, tapering to a point and dressed.

18. Transit stations will be designated by conventional signs with the number of the station marked on the guard stake. A sketch must be made and incorporated in the transit book showing the location of the transit line, as run, and with at least two tie measurements for each transit station taken at an angle of from 30 to 60 degrees, or as near thereto as practicable, to form a sharp intersection to fixed marks or to stakes securely driven nearby for the purpose. Four tie measurements when practicable will be preferred. Permanent transit points such as a cross cut on a fixed stone or solid rock must be selected when practicable.

19. The area to be mapped may be covered first by a system of transit stations established by means of triangulation, the stations to be as far as possible intervisible, and to be used as main stations for the meander or traverse lines. It may also be surveyed by running meander or traverse lines at once, when it is impossible or impracticable to conduct the primary work by triangulation. In this last case if the traversing is done at the same time on both sides of the rivers by two parties, check angles must be taken as often as possible on the stations of both traverse lines. If only one transit party is employed, the traversing must be done by circuits, the river being crossed at every two or three miles and traverse lines run on the other side returning to the starting point, thus closing the circuit. The circuit thus formed must close in the field and on the plans within permissible limits as may be set by the district engineer and must close also by computation within prescribed limits; the method of latitude and departures being used for plotting.

20. A true meridian shall be established at the beginning of the survey for each section, and also when connecting with the traverse system of adjacent sections. To do this follow the usual method of observation at elongation on circumpolar stars, Ephemeris being supplied for this purpose.

21. The azimuth of the base or starting traverse line will be determined from the true meridian as established and is to be carried forward through the triangulation or main traverse. At each transit station occupied, the azimuth of prominent objects in the line of view, such as church spires, corners of prominent buildings, chimneys, prominent and specially shaped trees, &c., should be taken.

The true meridian shall be used as the zero of azimuth, and all angles shall be read from left to right.

Correction and distribution of ordinary errors of observation and for change due to convergance of meridians will be done as directed by the district engineer.

22. All measurements of main transit traverse lines must be made with the greatest care and with steel tapes furnished by the department which have been tested for temperature and tension, the record supplied, and with plumb bobs. All such distances must be checked for errors of 100 or 50 feet, by reading of a stadia distance over the line during or after measurement. The temperature will be recorded by readings of supplied thermometers, and adjustment for temperature made and recorded. It will not be necessary to make corrections for differences in temperature smaller than fifteen degrees.

23. All computations of transit notes relating to triangulations and traverses, adjustments of measurements, and calculations to determine latitudes and departures of transit station, shall be made in computation books all of which should be carried on continuously through the entire work of each party.

Complete information should be given at the heading of each page of the calculation books in which triangulation or traverse calculations are made for all field work, reference being made to the number of the field book, page, &c.

It must be so arranged that a simple inspection of field note books, calculation books or other such records will show where and what the traverse or other work is and its results.

LEVELLING WORK.

24. The level work of each section will be done by the same force as the transit party.

25. Permanent connected bench marks must be established throughout each section at intervals not exceeding one mile.

Each section will assume a convenient datum whose elevation to the standard datum of the Great Lakes and River St. Lawrence will afterwards be determined when true elevation of the section bench marks can be permanently marked.

26. Water gauges should be established at the head and foot of each pool and as may be directed by the district engineer, and the zeros of all the gauges, whether used to establish sounding datum or for record of water surface will be connected accurately with the level net of the section.

27. The elevation of the top of all hubs or monuments set by transit party shall be taken. If such points are destroyed or lost the elevation of the ground where the hub was located shall be determined and recorded.

28. Connection shall be made wherever possible with any bench marks found on the railways in the vicinity of the proposed canal line, or any other bench mark used on other survey, if any.

29. The datum for all levels when reduced will be mean tide at Governor's island, N.Y., U.S.A., upon which all charts of the St. Lawrence river, above Montreal and of the Great Lakes are based.

30. All lines for establishing bench marks shall be run with two rodmen, alternately one forward, one back.

31. Each rodman shall keep separate notes of rod readings on all turning points and bench marks on which he holds and he shall compute their elevation when furnished by the recorder, with the height of the instrument, &c.

The recorder shall always read the rod after the rodman, make the necessary calculations and compare results with the rodman. If the results differ each person shall again read the rod before comparing results, and if the readings of the rod differ, another setting of the target shall be made by the instrument man.

32. Work must not be attempted during high wind. During very hot weather an effort should be made to begin work very early and remain out late rather than work during midday. During severely cold weather no attempt to run lines for establishing bench marks should be made, but secondary work should be carried out.

33. Foresights and backsights should be of equal length, and no sights over 300 feet long shall be taken except in the case of crossing rivers or deep ravines. In such cases as this precaution must be taken and the average of repeated readings at changed positions of rod and instrument shall be used.

34. If it is impracticable to take equal foresights and backsights, as soon as the steep slope is passed, enough unequal sights shall be taken to make such set balance.

35. Distances may be taken by stadia, pacing, or any other suitable method according to conditions.

36. The instrument must always be levelled carefully before setting the target. After setting it and before giving the signal 'all right' the level bubble must be examined. One rod No. 1 or No. 2 should always be read first, so that one rod is used as foresight first at one set up and as backsight first at the next set up.

37. The level must be examined daily or oftener, if necessary, for adjustment, the especially important adjustments being those for collimation, and of the level bubble.

38. Steel pins or points on solid rock, or similar staple points must be used as turning points in all cases. If steel pins are used they shall be firmly driven in the ground and the backsight pins shall not be removed until the foresight reading is completed and the recorder and rodman have compared results on the backsights.

39. Plumbing levels must always be used on levelling rods and must be kept in adjustment.

40. Bench marks or turning points left at the termination of the work at night, or for other causes as rain, snow, &c., must be selected with great care and located in such manner that there will be no danger of their being disturbed or tampered with in order that the rod may again be held on the same spot for procedure of the line.

41. Permanent bench marks must be clearly described not only with reference to the nearest base line station, but also to existing and easily identified features of the ground. A sketch shall be made showing the location of the bench mark and the reference marks referred to.

42. All circuit closures or checks by duplicate lines shall be distinctly noted and a careful reference made to the same check levels.

43. On duplicate lines of levels, the error closure of the two runnings, or the return levels to the starting point must fall within ·05.

44. The instrument at all times shall be protected from the direct rays of the sun, and when set up shall also be protected from high winds, before taking observations.

45. It is the intention that all elevations taken for the 5-foot contour lines be determined with the level by means of close cross-sections, or by the method of setting out squares at all places where there is a probability of some construction work being done or for all small areas likely to be submerged by the building of dams, &c. For all large areas where the 5-foot contour lines are required, the fixing of points and their elevations may be determined by stadia work for their future development in contour.

STADIA WORK.

46. In obtaining topography where building construction of some character is likely to be undertaken, ordinary transit work with chain or tape measurements of lines and determination of elevations by the dumpy or Y level will take preference over stadia method.

47. Where the locality is sufficiently open to permit its use the stadia method will be followed to obtain the topography.

A careful determination of the value of the wire interval of each instrument so used will be made by base line readings on standard unit rod and the interval factor established when a reduction table for that instrument can be computed for the reduction of the field shots or a diagram of critical change compiled:—See Johnson's 'Theory and Practice of Surveying' chapter VIII.

A careful sketch shall be made in a separate book if necessary (not necessarily to a scale) of the area mapped. Upon this sketch shall be shown the location of the shots taken, natural and artificial features, also the shape of the ground by contours.

48. The recorder, who will record the readings as called out to him by the observer, shall note the character of all shots taken, whether a contour (c.p.) a fence corner (f.c.), a stream (str.), a ditch, a water edge (w.e.), &c., using such abbreviations for these as may be convenient. In the back of each note book an index of the abbrevia-

tions used must be recorded; also an index of the notes to be found in the books; this index to be filled out after each day's work.

49. Each rodman shall keep a record of the number and character of the points at which he holds his rod, briefly noting them upon a slip of paper tacked on the back of his stadia rod. Each rodman should also be provided with a blank note book in which if occasion requires, or he is authorized to do so by the man in charge of the party, he can make a plain sketch, joining up the shots taken in any area which he may be assigned to work up, and which may be either inaccessible to, or too far removed from the man doing the sketching to make an intelligent sketch of the same.

50. At the intervals of each ten or twenty shots the rodman should call out the number of the shot to the recorder and the man making the sketches, to prevent any confusion in numbers, when the day's work is finished. The slips of paper used by the rodman shall be compared with the recorder's notes and any omissions in his notes supplied; and after which the usefulness of the slips of paper ceases and they can be destroyed.

51. All stadia notes must be reduced, checked and kept up to date, for difference of level and elevation in order that a constant check may be had on the work, and any corrections or omissions necessary supplied while the party is in the neighbourhood of the work.

52. Stadia circuits of from two to three miles in length must close within a limit of five minutes. The error in elevations for this distance should not exceed five-tenths of a foot; the error in the length of the circuit should not exceed the limit of one in eight hundred.

SOUNDINGS.

53. The force used on a sounding party will be made up to suit conditions and circumstances, this being left entirely to the judgment of the sectional engineer.

When soundings are made in winter time, on the ice, the sectional engineer may engage such teams and extra men as he may deem advisable to push the work rapidly.

When using boats for soundings, especially in difficult places, such extra men as are required to man the boats properly and safely may also be engaged temporarily.

54. Range stakes for soundings will be set in advance of the soundings, either by the sounding party itself or by the transit party according to the conditions and the instructions of the district engineer.

Range stakes shall be designated by the letters R or L according to their location on the right or left bank of the stream looking down the stream, and the number of the range 'R 25,' 'L 9.'

55. Sounding ranges should be located at intervals not exceeding 100 feet, excepting where the rivers or lakes, through which the canal will pass are deeper than 30 feet at low water, in which case sounding ranges may be located only every 400 or 500 feet. Soundings should be taken at about 50 feet intervals along each sounding range, these instructions to be varied to suit any conditions found, the object being to take sufficient soundings to enable the accurate drawing of five foot contours, the same as over the area outside of the limits of the stream or river. Where the depth of the water does not exceed 10 or 12 feet the sounding rod should be used. When feasible, soundings should be taken through the ice, but care should be taken to ascertain that the water may not be held back at some point by some ice or frazil obstruction, observation of the ice level being taken quite often.

56. The character of the material, as far as the same can be determined by the men making the soundings, shall be called out to the recorder and recorded in his note book; also any outcrops of rock that may be seen, or other information of value noted in connection with the future classification of the material.

57. Transit line sketches and elevations of the transit points by 'Y' level with the locations of these points should be furnished the sounding party, as a basis for their work.

58. Any circuit or secondary traverse lines run for the setting of sounding points shall be tied into the main transit line as a check for direction and elevation at from one to three-mile intervals. Soundings should always be taken going down stream if possible.

59. The elevation and any information bearing on high water marks shall be noted as already instructed. The elevation of the water surface of any stream, river or lake sounded shall be noted at each range taken and a note made whether surface is at low, medium or high stage, and a rough estimate made of the velocity of the water.

60. Gauges shall be established at different suitable points of the rivers or lakes, and arrangements made for regular observations during the whole time of the survey.

BORINGS.

61. A boring party shall consist of one foreman, three or four labourers, and such teams or boats as may be required to transport boring parties and tools.

62. Borings shall be made at such intervals along the line of the proposed canal location as may be necessary to develop the depth and profile of the rock surface, if within the limits of possible excavation for canal prism or structures; and also to determine the character of the material to be excavated or dredged, in order that, when the maps are plotted, a correct estimate may be made of the character of the work and the kind of each material proposed to be excavated.

63. The location of each boring must be made with reference to the station of some transit or stadia line, or connected with such existing features on the ground as have been already located, in order to accurately locate the boring on the map; also the elevation of the surface of the ground or water surface of the river or lake at which the boring is made shall be determined.

64. The man in charge of each party shall see that careful measurements are taken at each change of material found in the boring and a sample preserved.

65. It is desired to firmly impress upon those in charge of these borings the importance of the correct determination of the rock surface. This can be generally determined either by shifting the location of the boring and putting an additional hole, or dropping down one or more sticks of powder and firing them with a battery, after raising the casing pipe three or four feet.

66. A careful record must be kept by the men in charge of each boring party, in note books furnished for the purpose, of the character of each kind of material penetrated, the depth of penetration, and a sample preserved of each class of material as much as possible.

67. Boring parties will be under the control of such assistant engineer or other employee as the engineer in charge of the section may designate.

68. Borings will be made by the use of steel rods 'wash boring outfit,' earth or rock drilling auger or by such other means as the district engineer may decide according to conditions, the method adopted to be approved of by the resident engineer in charge.

DATA REQUIRED REGARDING PRESENT STRUCTURES.

Make a location on the standard sheets to a scale of 50 feet to one inch showing in detail all natural and artificial objects adjacent to present structures. For bridges show carefully all topography around, and general plan and profile of bridge, with dimensions and height of piers, length of spans, &c. If detailed plans of these bridges

are available they should be obtained and sent to the office of the engineer in charge at Ottawa to be filed.

70. In the case of the proposed canal line running along an existing canal, all details of the locks and sections of that canal should be shown on maps drawn to the above-mentioned scale, and complete detailed plans and specifications obtained if possible.

71. All timber slides on the river shall be carefully noted with all dimensions, also all piers and booms, wharfs, ferries, &c.

72. Detailed maps showing all water-powers as established, or in process of development shall also be made, and all data possible regarding these water-powers, or other available water-powers shall be collected.

REPORTS.

73. Each engineer in charge of a party shall make prompt reports at the end of each week to the district engineer in charge of his section; which shall state briefly the amount of work done, the approximate location of each kind of work in progress; stating separately, under the headings of transit and level work to what point the work is completed; giving the transit stations as well as the location, the number of days at work in the field, the number of miles run, and average run per day.

74. Under 'stadia work' they shall state in what section the party is engaged and the approximate amount of work completed; stating also the number of days in the field. A small sketch shall accompany the report showing the limits of the area mapped.

75. Under 'soundings' shall be stated the number of the transit station to which the soundings are completed, and its location, the number of miles of river sounded, the number of soundings made, the number of ranges taken, and the number of days in the field.

76. Under 'borings' shall be stated to what transit station the borings are completed and its location, the number of days at work, the number of borings made, the number of feet penetrated as classified under the several general headings, such as 'earth,' 'sand,' 'clay,' or 'gravel,' &c., and the total of feet penetrated.

77. In reporting the number of the transit station and its location, reference should be made to its distance from some town or village along the work. In addition to the above, any information of general interest or importance should be given.

78. Each engineer in charge of a section shall also make a report to the district engineer at the end of each calendar month. In the report a summary shall be made under the general headings as stated for the weekly reports, giving briefly the condition of the work in progress at that date, any work proposed to be undertaken, and any and all information bearing on the work.

79. Each district engineer shall make a weekly and monthly report to the engineer in charge at Ottawa; embodying the several reports from his engineers in charge of parties, and accompanied by any information of importance or by any suggestions.

The district engineers will be under the immediate direction of the engineer in charge at Ottawa, and all official communications from the district engineers shall be addressed to him.

80. Each district engineer, in the report submitted by him, shall state the date and location at which the several parties began work, the names of the employees, and the day upon which they reported for work. He should keep notes during the progress of the work, with the view to being called upon to submit a general report thereon, and also to its publication as part of the report of the engineer in charge.

81. Engineers in charge of parties and assistant engineers shall make such special reports as may be directed by their superiors.

EXPENDITURE AND ACCOUNTS.

82. Each engineer in charge of a party will certify bills for all necessary expenditure incurred in connection with his work, and will write above his signature the certificate: 'certified correct, goods received, prices fair and just,' or 'work performed,' as the case may be. Engineers must be very careful to purchase supplies at the lowest market prices obtainable.

83. For all necessary travelling or living expenses incurred in connection with the work as authorized by the district engineers or engineer in charge, the certificate will be: 'expenses incurred on government business,' to be signed by the party making the expenditure, to which will be added the certificate of the engineer in charge of party 'certified correct, charges fair and just.'

84. Regular pay-list forms will be supplied each party on which at the end of each calendar month will be entered the names of the engineering staff and all labourers employed on the party, with their rate of pay and number of days employed; the sheet to be certified to by the engineer in charge of party: 'certified correct, wages authorized.' To this pay sheet will be attached the bills duly certified for expenditure incurred during the month, a list of these bills being made on the return of account sheet, and a summary filled in as per direction on the blank forms to be supplied.

85. All pay-sheets and accounts will be sent to the district engineers who will examine them, and mark them 'approved' above their signature, if correct, to be forwarded then for payment to the engineer in charge at Ottawa.

Should the services of any employee terminate before the end of the month, an approved voucher accompanied by letter of explanation and sent to the engineer in charge at Ottawa will be paid.

86. Receipts for any expenditure by assistant engineers or other employees (except railroad fares or the like) exceeding five dollars must be procured whenever possible, and accompany each expense account.

Hotel bills must show each party's name, the dates and rate per day.

87. Employees will be expected to pay all personal indebtedness before leaving any locality.

88. All printed forms and books used in the work, as well as all stationery, instruments, &c., will be supplied from the head office at Ottawa on requisition from the engineer in charge of party and approved by the district engineer.

OFFICE WORK IN DISTRICT ENGINEERS' OFFICES.

89. The office of each district engineer will be located as may be decided upon by the engineer in charge.

90. The notes and maps as sent in to him by the sectional engineers will be replotted in his office, transferred on continuous mounted paper, so as to form a continuous working plan with corresponding continuous profile of the river.

The above rule as to the plans to be made during field work will be subject to further directions, in accordance with suggestions to be made by the district engineers, as soon as work has been started.

91. On each map or section of continuous plans, shall be written in pencil, the number of the sheet, the scale upon which the work is plotted (400 feet to one inch except for details when otherwise ordered); the district whether 'Nipissing,' 'Ottawa' or 'Montreal,' the bases or co-ordinates used and reference shown by file number, to the note books, whether transit, level, stadia, sounding or boring books, in which the notes are to be found from which the sheet is plotted. A true north line shall be drawn on each map sheet, or at every two miles on continuous plan.

92. In plotting points on the plans or map sheets, the decimal point will represent the exact location. When it is not practicable to do this a small cross shall be made, as designating the location, and the elevation written near it.

93. Consecutive location sheets shall have the topography carried to the upper, lower or right edge of the sheet so that a junction may be made with the following sheets.

GENERAL.

94. All men employed on the survey will be expected to be courteous in their treatment of each other and the general public.

Intemperate habits will be deemed sufficient cause for the prompt dismissal of any employee.

95 All cases of insubordination shall be promptly reported to the chief engineer.

96. In case of any employee being found incompetent to do his work properly, it will be the duty of the sectional engineers and district engineers to report the case at once for the action of the chief engineer.

97. In making surveys care must be taken to do as little injury as possible to private property.

98. Employees must promptly carry out the instructions received, and in case such instructions are not thoroughly understood, the person receiving them should ask his immediate superior to explain them, to the end that the desired results may be secured.

99. Employees must not deviate from instructions received.

100. The specified degree of accuracy should be obtained with the least expenditure of time and money compatible therewith.

DEPARTMENT OF PUBLIC WORKS,
OTTAWA, ONT.

APPENDIX B.

TEST BORINGS.

General information as to materials encountered at all the points investigated, as compiled by Mr. H. M. Davy, engineer in charge of test borings.

Test borings were made and locations investigated over the proposed line of the Georgian Bay ship canal between Bout de L'Ile and Lake Nipissing.

METHODS.

Three methods were used to make test borings:—

1st.—"Pierce" well boring machines.

2nd.—Test pits.

3rd.—Hollow pointed rods.

1st.—Where possible the borings were made with a boring machine and if an occasional boulder or compacted material was encountered, dynamite was used to force it aside or break it up.

2nd.—Where considerable boulder material or very coarse gravel was in evidence, it was necessary to dig test pits, as the boring machines could not be used economically in this material.

3rd.—In soft material under water, or in swamps, hollow rods, pointed at one end, were sometimes used to locate rock or hard material.

DIFFICULTIES.

Difficulty was experienced in many localities where boulder drift material, or coarse gravel was encountered under water or in low places, when test pits could hardly be dug and kept dry, owing to seepage water.

The borings were made along the then proposed centre line of canal, lock sites, dam sites and embankments in water.

LOCATION.

The location of each boring was made with reference to the station of some transit line, and where lines had not been run, they were connected with prominent features which were afterwards tied into the survey, to enable the accurate placing of the borings on the plans. The elevation of the ground or water surface where boring was made was also determined.

IMPROVEMENTS DUE TO BORINGS.

In many localities, the line of canal and sites for locks and dams were improved upon after borings had been made, which showed unsatisfactory foundations or heavy excavation.

BORINGS.

On first examining a locality, borings were made about 400 feet apart, and if they disclosed great irregularity of the material penetrated, then intermediate holes were made, but if the material was regular, they were spaced farther apart.

Where structures were contemplated, holes were put down closer together, the purpose being to locate solid rock surface.

Borings were carried to below the proposed grade of the 22-foot channel or to bed rock, if it was encountered above grade.

DEPTHS.

For lock sites, the excavation extended to bed rock when possible, and for dams and embankments to bed rock or hard bottom. No diamond drill was used, so bed rock was not penetrated.

SAMPLES.

Samples of the different classes of material penetrated at each boring were taken and kept in properly labelled 4-ounce bottles.

BORINGS ON PLANS.

Nearly all the borings (85 per cent) that were taken are located on the general plans and are designated by a red circle enclosing the number.

Vertical sections, scale 10 feet to 1 inch, are also shown in groups upon the plans and each is numbered to correspond with the number in the red circle.

MACHINE.

The boring machine employed is shown in fig. No. 1. The apparatus used in making deep test pits is shown in figures Nos. 2 and 3.

The total number of borings made over the entire route was 2,990 with a total depth of 27,000 feet making an average depth of say 10 feet.

The total number of borings and vertical sections shown on general plans is 2,584.

In the locality around Montreal island, 349 borings were made at different times between June 23, 1905 and July, 1907. 186 borings were made on the Lake St. Louis route between Bout de l'Ile and above Ste. Anne. 163 were taken over the Back river route between Bout de l'Ile and Ile Bizard.

BOUT DE L'ILE REACH.

Mileage starts at junction with St. Lawrence Ship Channel.

At Bout de l'Ile, mile 3, a boring was made to a depth of 110 feet, rock being located 87·5 below sea level, (elevation 87·5) the material penetrated was a mixture of sand and clay. This material blue clay and sand, probably extends from the ship channel up the Back river to Des Prairies, miles 0 to 8. Boulders and gravel are in evidence on the surface of Ile Bourdon and also in the river bottom, but they seem to lie upon the clay, because all the piers of the Great Northern railway bridge are founded on piles.

A trial line across the foot of Montreal island was examined, 29 borings being made averaging 30 to 40 feet deep each. The material was sand and clay throughout. Three borings were made at the St. Lawrence end of this line to test for a lock site. They developed rock surface about 50 feet below surface, say, elev.-18 below sea level.

At the upper end of Ile Ste. Thérèse, a boring 75 feet deep failed to locate hard material.

Two dam sites were investigated at the head and foot of Ile Macheau and seven borings made showed sand and clay to a considerable depth, 60 feet on rock

PRAIRIES REACH.

At the chosen lock site rock appears at ground surface and the small mill race nearby shows limestone bed rock plainly. The river bottom above and below the lock is solid rock. Both shores indicate an eruption through the Trenton.

There is no further excavation except at the head of this reach in the vicinity of Visitation island. The river bottom is an evenly stepped limestone rock, over which the water falls in a succession of small cascades. Bed rock is visible all along the shore of Visitation island, being as high as elev. 50 at the head.

RECOLLET REACH.

(March and April, 1907.)

Three test pits were made to determine rock for the Récollet lock foundation, and the limestone forming the bed of the river below was again found at about elev. 40.

Above this lock is a thorough cut canal extending to Oka lake. Over the first four miles (mile 17 to 21½) up to Cartierville, 47 test pits were made showing boulders, sand and gravel to below grade, but no rock, although hardpan was encountered at the upper end.

From Cartierville to the head of Back river (miles 20 to 30), that is, the foot of Oka lake, the canal line cuts through a series of points along the North shore, and through the bays between these points, there are six embankments which form the outer side of the canal. In all, 78 borings and test pits were made, showing the material through the points to be boulders, sand and hardpan to below grade, except at mile 26½ where for 1,000 feet the rock is 15 feet above canal bottom elev. 68, and along the north of Bigras island, where it is 18 feet above grade (elev. 71).

Through the bays it is important to know the foundation upon which the canal embankment will rest. Fortunately, it proves from the following detail of borings to be compact sand and clay.

BACK RIVER—EMBANKMENTS IN RIVER.

No. 1.—The foundation of embankment between mile 21 and mile 22, shows 30 feet sand and clay on bed rock elev. 30·7.

No. 2.—Between mile 22 and mile 22½ shows about five feet of sand and clay on rock, about elev. 49·0.

No. 3.—Between mile 23½ and mile 24¼ shows sand and clay on boulders and hardpan.

No. 4—Between mile 24½ and mile 25½ shows bed of river, boulders, sand and clay.

No. 5.—Between mile 26 and mile 26½ shows solid rock on the bed of the river.

No. 6.—At mile 27 shows sand, clay and gravel for about seven feet on top of bed rock. A small island 300 feet below Bigras island is solid rock, so that the foundation for the regulation sluices at that point is assured.

On both sides of the Lallemand rapids, mile 28 to 29, some 28 test pits and examinations of the river banks were made during May, 1906. Bed rock was disclosed considerably above water surface up to the head and the river seems to have cut its bed into the Trenton limestone, which is now three feet to eight feet above grade, elev. 56 to 61.

At the head of the rapids, mile 28¾ to 29¾ the rock dips rapidly below grade, and is overlaid with clay.

During March, 1906, borings were made through the ice on Oka lake from Lallemand rapid westward. At mile 30, rock was encountered about eight feet above grade, elev. 61, for a distance of 2,200 feet along the north of Ile Bizard.

Beyond this to near Oka village, where the back and front lines join, miles 30 to 37, the borings show clay to below grade, except at mile 36 where rock rises about four feet above grade, elev. 57, for 1,000 feet.

Several lines were tried, through the Back river before a canal along the north shore was determined upon in 1907 and during 1906 two lock sites were examined, one on the south and one on the north side of the river.

South of the White Horse rapid, mile 25, two test pits were made showing sand and clay on boulders at elev. 53.

On the north side above Paton island, mile 23, borings showed sand, clay and sand down 46 to bed rock, elev. 21.

Both these trial lines led through the centre of Bigras island and in 1906 (July), eight test pits through boulders, clay and cemented material, determined rock surface from elev. 56 to 72.

MONTREAL REACH—HARBOUR TO MILE 5.

Ten borings were made during March, 1907, between Montreal lock and Verdun lock, which show clay, gravel and boulders on bed rock, which, however, is entirely below the required bottom of channel.

At Montreal lock site, the rock is to be seen at about elev. 20 and it continues flat up to the Grand Trunk bridge, always below grade. In Montreal harbour, just below the lock, there is a shale rock dredging.

In 1905,borings were made along the north shore of Nun island, 10 in all, showing rock about elev. 30, and overlaid with sand and clay. Sixteen borings were also taken in front of St. Gabriel and Verdun along the outside toe of the dyke showing sand and clay on shale rock, the surface of which varies from elev. 25 to 30.

The same year, a trial line along the west of Verdun village through Cote St. Paul to the Lachine canal, was bored. Seventeen borings showed the rock to rise from elev. 30 at the river edge to elev. 40 near the aqueduct, and up to elev. 72, near the Lachine canal. The proposed bottom was elev. 44.

LAKE ST. LOUIS REACH.

In January, 1907, an examination by test pits and borings along centre line, and observations along the shore at Verdun lock site, indicated that the rock rose sharply from water edge, elevation 35 to elevation 55, all along the shore. The tail-race of the power-house was excavated in limestone.

Through the Verdun cut, miles 5¼ to 8, 21 borings were made showing boulders, hardpan, and sand and clay to below grade, except between mile 6 and mile 7, where slate rock crops up above grade for about 4,000 feet in length, the highest part being elevation 60.

Between the head of the aqueduct, mile 8, and Lachine locks, mile 10½, 23 borings were made in the bed of river, along the foot of the high bank Lachine, which show gravel and boulders on bed rock. These borings were made from the edge of the ice. The strong current broke away the ice below Lachine bridge, however, causing a gap about a mile in the borings. Rock at elevation 60 is to be seen at the Lachine bridge. Beneath the water, rock could not be located when covered with boulders and gravel.

Between mile 10½ and mile 11½, information received shows solid rock in bed of river (Lachine canal entrance).

Between mile 11½ to mile 15, Lachine to Dorval, no borings were made on account of the strong current and lack of ice.

Between mile 15 and mile 16, ten borings show gravel and boulders on grade.

Between mile 16 and mile 20, 28 borings were made which show clay and sand to below grade.

Between mile 20 and mile 22 is deep water.

Between mile 22 and mile 23, seven borings show clay, gravel and boulders to grade.

Between mile 23¼ to foot of Ste. Anne rapids, mile 24¾, 27 borings were made showing gravel and boulders on bed rock (Potsdam and sandstone) about 15 feet above grade for a distance of about 4,000 feet.

A trial line was examined ¼ mile north of that adopted between mile 23 and Ste. Anne; 9 borings were made from a scow, which show sand, gravel and boulders on rock.

OKA REACH, MILES 25-40.

The old outside lock Ste. Anne will be the site for the one proposed, and from information kindly furnished by Mr. Marceau, superintending engineer, Quebec canals, the rock surface was found to be about elevation 64.

Above the rock, mile 25 and mile 26, 17 borings were made in March, 1907, which show 2 to 4 feet of boulders and gravel on hard material, probably rock.

Between mile 26 and mile 30, 4 borings were made showing sand and clay to below grade.

Between mile 30 and mile 38, there being deep water, no borings were taken.

Between mile 38 and mile 41½, two routes were investigated, and 63 borings made, 20 via the route north of Hay island, and 43 via the route south of Hay island, all borings showing sand and clay to below grade.

Between mile 41½ to near mile 49 is deep water and no borings were taken. But just at mile 49, there is 4 to 9 feet excavation for 1,000 feet in length, which, judging from the surroundings, may be classed as boulders and clay, probably piled up by ice action.

POINTE FORTUNE REACH.

At Pointe Fortune, between miles 49 and 52, 85 test pits and borings were made in July, 1906, for lock site, canal and dam site.

At the approach to the lock, 12 borings show boulders, gravel, clay and sand, on bed rock, a few feet above grade.

For lock site, 6 borings, some 40 feet deep, show clay on bed rock, 22 to 35 feet above grade, elevation 75 to 88.

On canal line from head of lock, mile 49½ to mile 50, 17 borings show muck, sand, clay and boulders to below grade; from mile 50 to mile 50¼, 7 borings show muck, sand and clay to below grade from mile 50 to mile 51¼, 36 borings show muck, sand and clay on shale rock, elevation 108, about 15 feet above grade; the balance of the line to deep water shows sand and clay to below grade.

For the dam site at Dewar island, the investigation and borings showed shale rock in bed of river, and a few feet below surface on south shore and Dewar island; on the north shore, borings show rock 6 to 8 feet below surface.

Between mile 52 and mile 58, there being deep water, no borings were taken.

OTTAWA REACH.

On the Ottawa reach from the foot of the Grenville or Long Sault rapids, mile 59 to mile 119, 232 borings and test pits were made.

At the Long Sault rapids, the adopted route is on the south side of the river, 30 borings and test pits were made here during August, 1906. At the lower entrance of the approach to the Hawkesbury lock, the investigation showed a chazy shale rock in the bed of the river about 10 feet above grade.

At the lock site, chazy shale rock is in evidence at surface, about 20 feet above grade.

From the head of the lock site to the Hawkesbury Lumber Co.'s piling grounds, mile 61½, the test pits showed about 5 feet of boulders and loam on chazy shale rock 5 to 15 feet above grade.

From mile 61½ to mile 62 in the mill pond, the investigation showed boulders and gravel presumably on rock 4 to 14 feet above grade.

From mile 62 to deep water mile 64, the borings showed sand to below grade.

Two alternative lines were investigated during August, 1906 on the north side of the river, leading up to the village of Grenville.

The first line entered the north shore opposite mile 60 and followed generally the course of the Grenville canal, for about two miles, entering the river again at the head of the rapids, and joining the channel of the chosen route at mile 64; 37 borings were made.

At the lower approach to the lock, the investigation showed a chazy shale 5 to 10 feet above grade, and at the proposed lock site, from 10 to 15 feet above grade. From the head of the lock to the Great Northern railway bridge, the test pits showed about 4 feet of boulders, gravel and loam on solid rock 5 to 20 feet above grade.

Above the Great Northern railway bridge to the proposed upper entrance, the test pits showed rock surface about 20 feet above grade, elevation 133, and covered with excavation from the old canal.

From the upper entrance, for about 1,200 feet in length, the bed of river shows boulders and gravel on rock about 4 feet above grade, elevation 117; about 1½ miles further up, the borings showed sand and fine gravel to below grade.

The second alternative route, which leaves the river opposite mile 59½, follows along the north side of the Grenville canal for about 2 miles, then through a depression back of the town of Grenville and into the Ottawa river at Kingsey bay.

Passing around the north end of a sandy shoal, it connects with the chosen channel, about mile 65; 47 borings were made.

At the approach to the proposed lock, investigation showed a chazy shale rock in the head of the river, which is 3 to 6 feet above grade, elevation 96 to 99.

At the proposed lock site, chazy shale rock is in evidence 10 to 15 feet above grade, elevation 103 to 108.

From the head of the lock for a distance of 1½ miles, the test pits show about 5 feet of boulders, gravel and sand on chazy shale rock 10 to 20 feet above grade, elevation 123 to 133, and for the next ½ mile, 30 feet above grade, elevation 143. Through the swamp back of the village, the borings show about 6 feet of muck, sand and clay on boulders and gravel, 30 feet above grade. Further work in these test pits was prevented by leakage from the swamp; but the boulder formation evidently overlies solid rock, which was encountered at the surface near the railway.

At the upper entrance, the borings show sand and clay to below grade, and from here to deep water, sand and fine gravel to below grade.

DAM.

A dam site at mile 62 above the rapids, was investigated, and 5 test pits made on the islands showed solid rock at elevation 126. In the bed of the river, boulders are in evidence, presumably on rock, and along the north shore are ledges of rock which extend into the rapids.

During March, 1906, 118 borings were made through the ice between Ottawa and Grenville. From mile 64 to mile 91, there being deep water, no borings were taken. Below Thurso, mile 92½ to mile 93½, 9 borings were made which showed sand below grade.

An alternative line at mile 91, north of Horse Shoe island, was investigated and 9 borings made which showed sand to below grade.

From mile 93½ to mile 106½, there being deep water, no borings were taken.

Near Angers village, between miles 106½ and 107½, 10 borings were made which showed sand to below grade, and between mile 109 and 110½, 21 borings also showed sand to below grade.

Above and below East Templeton, mile 113 to mile 118, 70 borings were made which indicated sand to below grade, except 4 borings opposite the lighthouse, which showed boulders and gravel on solid calciferous rock at grade, elev. 117.

From mile 118 to mile 120, there being deep water, no borings were taken.

HULL REACH.

At mile 120, the line leaves the Ottawa river to go behind the city of Hull. At the approach to lock No. 1, 21 borings were made during April, 1906, mostly in the bed of the creek. These borings showed 8 and 10 feet of sawdust, sand and gravel on limestone rock about 7 feet above grade, elev. 125.

At the proposed site of lock No. 1, the test pits and borings showed 6 to 20 feet of sand, boulders and gravel on rock 15 to 35 feet above grade. In the east end of reach, between locks 1 and 2, investigation showed 6 to 8 feet of gravel on rock, elev. 150, and in the west end, rock at surface.

AYLMER REACH.

At the proposed Hull lock No. 2, the investigation showed rock about 2 feet below surface, elev. 185 to 190.

From the head of the lock for a distance of 1,500 feet, rock is in evidence at surface, and for the next 1,600 feet, rock is covered with varying depths of boulders and gravel; a cutting at the crossing point of the Hull Electric railway shows a depth of 10 feet.

On the bank of the river solid rock is seen at surface about elevation 185.

The south side of the river from Rideau falls to the Chaudiere is a limestone cliff.

The investigation of the proposed dam site above the Canadian Pacific railway bridge showed solid rock on both shores of the river, in the river and on the several small islands which the dam crosses.

From mile 122½ to mile 126½ there will be no excavation.

At Deschenes, mile 126½, the investigation showed about 2,800 feet of rock from 4 to 16 feet above grade in the bed of the river.

During March, 1906, 7 borings were made through the ice at mile 147 showing sand to below grade, and 7 borings at mile 149 showed sand and clay to below grade.

At Pontiac bay, two lines were investigated. Over the northerly one 113 borings were made during December, 1905, which showed clay on rock above grade in the bed of the bay, and limestone rock at surface above water.

Over the chosen line, 9 borings were made during October, 1907, showing sand to below grade under water, except at Hudson's Point where rock is encountered 2 to 7 feet above grade, elevation 175 to 180 for about 1,000 feet in length; the materials above water are limestone and gneiss rock at surface.

ARNPRIOR REACH.

At the proposed Chats lock site, gneiss rock is visible at surface.

Above the lock all the dry excavation will be gneiss rock.

In the beds of the several bays crossed, a considerable deposit of sand and clay is encountered.

Between miles 156 and 157, considerable wet excavation is required, the investigation here showed a crystalline limestone, 2 to 15 feet above grade.

During October 1907, a dam site was investigated at about mile 156½ and borings made; on both sides of the river, limestone rock is visible at surface; near the south

shore on the two small islands, the borings showed 2 to 12 feet of sand on rock, at elevation 223 to 234. In Black bay, a boring showed 12 feet of sand and clay on rock, elevation 211.

Between mile 158 and mile 162, there are a few small humps of boulders, gravel and clay above grade.

Opposite Castleford between mile 168 and 169, 3 borings were made through the ice on the chosen line showing clay to below grade. About 2,000 feet south of this line, 4 borings were made which showed rock 2 to 6 feet above grade and consequently the line was moved to the north.

From mile 169 to mile 174 owing to deep water no borings were taken.

At the approach to the Chenaux lock, the investigation showed gneiss rock at surface.

PORTAGE DU FORT REACH.

At the Chenaux rapids, an investigation was made in October, 1907, for a dam and lock site. At the proposed lock site on the Chenaux islands, gneiss rock is in evidence, the surface being very rough, but averaging elevation 275.

Over the proposed line of dam, rock shows up at surface on six of the small islands, which the dam crosses. On Elliott island, the rock is covered with from 2 to 6 feet of sand and clay. In the bed of the north channel there is a considerable deposit of sand and clay, and the shore of the river for 1,000 feet back, is covered with 2 to 4 feet of earth. The Ontario shore is practically a rock cliff.

From the head of the lock to Portage du Fort, mile 178½, owing to deep water, no borings were taken.

A trial line was investigated and 28 borings were made through a depression in rear of the village of Portage du Fort.

At the lower end for 1,000 feet in length, borings showed sand and clay on rock 7 to 27 feet below grade, elevation 251 to 231. Through the balance of the line the borings showed muck, sand and gravel on rock from grade to 30 feet above. All the rock in this vicinity is a crystalline limestone.

From Portage du Fort, mile 179, to the foot of Rocher Fendu lake, mile 184, there will be slight excavation off the tops of the several small islands and points; no borings were taken, but gneiss rock is in evidence with pockets of earth and boulders.

Between mile 180½ to mile 182, a trial line was investigated in November, 1905, through the Lallemand sny, on the south shore, and 32 borings made, which showed sand and clay on gneiss rock 15 feet above to 25 feet below grade line.

In Rocher Fendu lake, no borings were necessary; the small islands up to lock No. 1, mile 187½ are of gneiss rock.

ROCHER FENDU REACH.

At the proposed Rocher Fendu lock No. 1, rock is visible, the river banks on each side being rock cliffs.

From the head of lock No. 1 to the foot of lock No. 2, the excavation to come off the tops of the small islands and points will be rock.

COULONGE REACH.

At Rocher Fendu lock No. 2, the rock is to be seen at surface.

From the head of lock No. 2 to mile 193, limestone and gneiss rock are exposed on the surface of the islands and points.

Between mile 193 and 194½, 12 borings were made in August, 1906, which showed gneiss rock at surface, and also in the bed of the river.

From mile 194½ to 197, however, 12 borings showed sand to below grade.

Opposite La Passe, mile 198 to 199½, 5 borings were made showing sand and clay gravel, but the bed of the river is below grade.

From mile 199½ to 201, 20 borings made during March, 1906, showed boulders and gravel to below grade.

A route was tried through a channel south of a small island between miles 200 and 201, and six borings made, which showed boulders and gravel to grade, except on south shore where rock is visible at surface, elevation 347.

Two routes were examined at the east end of Coulonge lake during March, 1906. The first line passes close to the mouth of Coulonge river and swings outside the islands, following the north channel to Pointe Sèche. Twenty-two borings were made and two test pits dug on a small island. Nineteen borings, east and west of this island showed sand to below grade, but the group around the island disclosed boulders and gravel on limestone rock 5 to 8 feet above grade, elevation 333 to 336.

The second line of borings was taken 700 feet south and almost parallel to the first. Twenty-three borings and test pits indicated mud and sand to below grade, except over the small island north of Correll island, where boulders were encountered.

The channel was selected half a mile south of these trial lines, however, and 7 borings were made along it in August, 1906, from mile 201½ to 202½. These showed sandy clay and gravel with boulders to below grade.

From mile 202½ to 205½ in Coulonge lake, owing to deep water, no borings were taken.

Between mile 205½ and 207½, 23 borings were taken in February, 1906, all of which showed sand and clay to below grade.

From mile 207½ to 209 is deep water.

Between mile 209 and 212, borings and test pits were made in November, 1907, for the canal, lock site and dam site. At the approach to the lock, the borings showed sand and gravel on limestone rock, elevation 336 to 348.

CALUMET ROUTE (ALTERNATIVE).

Eighty-two borings and test pits were made over the alternative route through the Calumet branch of the river via Bryson and Campbell's bay to Coulonge.

Leaving the Rocher Fendu route at mile 183, a quarter bend to the right leads to Mountain lock, a mile distant.

Excavation is necessary along the edge of Hay island and at Sable rapids, but only to a depth of 2 to 10 feet in sand and clay.

Just below the lock, the entrance requires excavation some 20 feet deep, which, however, appears to be all earth.

Two lines of borings were made, November, 1905, and finally the lock was placed about midway between them.

The 21 borings taken indicate an area of rock at about elevation 285 which is overlaid with clay, sand and gravel.

Above the lock, the entrance channel will be in sand and clay to grade.

For the dam site at Mountain chute, the investigation shows limestone rock at surface on both shores and in the river bed.

At Dargis rapid, mile 185½, there is 2 to 7 feet of sand and boulders above grade for about 1,000 feet in length.

At the Calumet falls, one mile below Bryson village, two lines were investigated for lock and canal, during October 1905.

Via the selected route, 7 borings were made.

At the approach below the lock, mile 187, the investigation showed about 1 foot of sand on limestone rock 10 to 20 feet above grade, elevation 303 to 313.

At the proposed lock site, the investigation showed limestone rock at surface.

Above the lock for a distance of 1,700 feet, rock shows at surface.

On the Bryson side, the point just below the village, showed sand and clay to below grade. The dam site, however, is on solid rock of which the river bottom is composed.

TRIAL LINE.

Another route was investigated and 15 borings made through the gully, west of the Calumet falls.

At the lower end, the investigation showed sand and boulders on rock, about 15 to 35 feet above grade, elevation 308 to 328, and for 4,000 feet further up, borings showed sand and clay on rock 5 to 85 feet above grade, elevation 333 to 413.

For the next 1,000 feet, the borings showed sand and clay to below grade. At the head of Worrell bay, mile 188 ,two borings showed sand on rock, 35 feet above grade.

From above the Bryson bridge, mile 188½ to mile 200, following the river, the soundings show 2 to 6 feet of excavation. No borings were made, but investigation along the shore indicates sand to below grade.

At mile 200, a boring showed 36 feet of sand and clay to 11 feet below grade.

At mile 201, the line leaves the river, passes Grand Marais lake and across the peninsula to Fort Coulonge, mile 203; nine borings were taken October 1905, all of which showed about 50 feet of fine sand and clay to below grade.

One boring, 110 feet deep, was made in the village, through 30 feet of fine sand, 72 feet of clay and 8 feet of gravel, but without reaching rock as far down as elevation 253. A test boring was made at the water edge, mile 203, and showed fine sand and clay to a depth of 46 feet, elevation 316. This indicates that soft material extends out past Frost island.

From mile 203 to 204½, no borings were made, but the surroundings indicate sand and clay to below grade at least.

Opposite La Passe, 7 borings were made across the point; these showed sand to below grade.

Another line was investigated in September 1905, leaving the Calumet river at mile 201. It passes through Grand Marais lake and across the several bends of the Coulonge river, and enters the lake just below Pointe Sèche; nine borings were made, all of which showed sand and clay to below grade.

PEMBROKE REACH.

At the Paquette lock, the investigation in November 1907, showed about 15 feet of boulders, gravel and sand, on a roof of limestone rock, elevation 350 to 354 over an underground water channel, above and below the lock site; about 1,200 feet above the head of the lock, limestone rock is visible at surface.

From mile 210 to 212, about 10 small islands and part of the main shore were investigated; the islands at mile 210 show rock at surface, elevation 351. At Fitzpatrick island and the two small islands above it, the borings showed boulders and gravel to grade. At Marcotte island and the two small islands below it, rock is in evidence at the suface. On the main land, just below O'Brien's bay, investigation showed boulders, gravel and sand on rock above grade.

The three small islands at mile 212 showed sand, gravel and boulders to below grade.

A proposed site for the dam was investigated in November 1907 at about mile 209½, starting at the lock site and extending in a straight line across the lower end of Fitzpatrick and Reid's islands, and 1,200 feet on Allumette island. The borings made over the 800 feet from the lock to the water edge, showed boulders, gravel and sand on limestone rock at elevation 348 to 354, but beneath this elevation is an underground channel.

On Fitzpatrick island, the elevation of the rock is 350 feet, and also on Reid's island.

On the shore of Allumette island, rock is seen at elevation 350, but inland to the desired contour line, a distance of 1,200 feet, borings show boulders, sand and clay, to a depth of 16 feet at the extreme end.

Another route from Coulonge lake via Hennessey bay was investigated in February 1906, and again in September of the same year, in order to avoid the questionable foundation at Paquette due to caverns in the rock. Branching into Hennessey bay from mile 204½ to mile 207 and crossing the Westmeath peninsula to O'Brien's bay, mile 209, it connects with the Pembroke route 1,500 feet further on, mile 212.

In Hennessey bay, 15 borings taken during February 1906, showed clay to below grade and, although the line has since been moved about 700 feet north of these borings, the material there would evidently be the same.

At the approach to the lock, the borings and test pits indicated boulders and clay on limestone rock, from 14 to 17 feet above grade, elevation 342 to 345.

At the proposed lock site, the borings showed 8 to 14 feet of muck, sand and clay on rock 26 to 32 feet above grade, elevation 354 to 360.

Above the lock, for a distance of about 2,600 feet, the borings pointed to from 1 to 15 feet of sand and clay, and boulders and gravel on rock, which was 6 to 33 feet above grade. Over the next 3,000 feet, the material consisted of muck, gravel and boulders to 14 feet above grade, elevation 362. Owing to water, the boulders and gravel could not be penetrated, so rock was not located.

At the road crossing near O'Brien's bay, limestone rock is visible at surface elevation 370; but the balance of the excavation as far as deep water, will be sand, boulders and gravel down to grade.

The proposed dam for this route will close the East or Timber channel, just below O'Brien's bay and the Dog channel west of Marcotte island, about half a mile below its head. At both these dam sites, rock forms the sides and bottom of the river.

Resuming the route to Pembroke, from mile 212 to 222 no borings were taken, the water being amply deep, except between mile 215 and 216 in Lower Allumette lake, where about 2 feet of excavation, for about 1,000 feet in length is required, evidently sand from the appearance of the shores.

From the foot of Allumette rapids to the head, both shores and the bed of the rapids consist of chazy shale rock. It rises from 2 feet above grade in the middle of the rapids at the foot to 12 feet above grade at the head a distance of 7,500 feet.

At the foot of Morrison's island through which the extra channel for the increased flow is located rock is seen at surface, elevation 360 to 370 for 1,800 feet in length.

An investigation was also made on Beckett's and Moffatt's islands as to excavation for increased flow of water the borings showed about 2 feet of loam and boulders on chazy shale rock, elevation 368.

At the head of Morrison's island, mile 223 to 224, 16 borings were made in the river showing clay and gravel to below grade.

During February, 1906, 13 borings were made through the ice opposite Pembroke, between mile 226 and 227; all but two of these show the surface of the hole to be below the adopted grade, and the materials penetrated to the boulders, gravel and sand to below grade in the other two borings.

Between mile 230 and 232, near Leblanc island, 35 borings were made during February and September, 1906, showing boulders, gravel and sand to below grade.

For the route via Pembroke, a dam would be necessary across the Culbute channel, and the site investigated above the old Culbute locks, mile 222½, as stated, shows granite rock at surface on both sides of the river.

CULBUTE ROUTE (ALTERNATIVE.)

During August, 1906, an alternative route was investigated via the Culbute channel, leaving the main channel at mile 208½ passing to the north of Allumette island and connecting with the Deep river at mile 233.

Near Waltham station, mile 210, 12 borings were made which showed sand and clay to below grade, and one of these borings, mile 209¼, was made to a depth of 80 feet, through sand and clay without reaching rock. A lock at this point was therefore abandoned. Above this, as far as mile 211, the borings showed sand to below grade.

The line actually estimated does not coincide with the borings made, but these indicate clearly that between mile 208½ to 211 there is sand to below grade.

The lock is located in McDougal Point, and at the approach to the lower end, the investigation showed limestone rock, 2 to 12 feet above grade for about 2,000 feet in length.

At the lock site, it is 17 to 30 feet above grade, and rock underlies the proposed dam. Above the lock to Chapeau, 5 miles, is deep water and no excavation is necesary, but at the village a small amount of rock excavation will be required near the proposed bascule bridge. At Chichester, mile 219½ there is again excavation in gneiss rock, 2 to 12 feet in depth for about 400 feet in length.

At the old Culbute locks and for about 1 mile above, the investigation showed gneiss rock, both sides of the channel, 2 to 60 feet above grade.

Between mile 223½ and 225¼, owing to the depth of water, no borings were necessary.

From mile 225¼ to the junction of the two routes, mile 227½, the several small islands show rock at surface.

For the Culbute route a dam across the main channel would be required at Morrison's island where there is rock at surface or slightly beneath.

No borings were taken on the several small islands and shoals between miles 233 and 236½, as gneiss rock is visible at the surface.

Near Fort William, Que., mile 237 and mile 238, 4 borings showed boulders and gravel to below grade.

At mile 239, 3 borings were made, 2 of which show gravel and sand below grade, 1 shows rock in the bed of the river above grade, elevation 356, but this boring is just outside the proposed channel.

Through Deep river, mile 239 to 265½, owing to very deep water, no borings were necessary, though one was made at mile 261. 800 feet north of centre line, off a sand point just above Fraser's Lumber Depot, this boring showed sand to considerably below grade.

DES JOACHIMS REACH.

During September, 1906, 21 borings and test pits were made at Des Joachims for lock, canal and dam.

At lock and just below, 10 test pits were made which showed about 6 feet of boulders, sand and gravel on gneiss rock 20 to 60 feet above grade, elevation 368 to 407.

Above the lock, 5 test pits show boulders, gravel and hardpan to below grade, except in one pit where rock shows up 5 feet above grade, elevation 393·0.

For the dam and regulation sluices, 6 borings were made which showed boulders, gravel and sand for about 5 feet to rock.

On all of the small islands around mile 267, rock shows up at surface.

From mile 267 to 271, owing to deep water, no borings were taken, but an investigation was made of the small island or shoal at mile 270½, about 300 feet north of the centre line, and proved to be boulders and gravel to grade.

During August, 1905, borings were made through McConnell's lake, an old channel of the river. Altogether 39 borings were taken, of which 18 were in the bottom of the marsh extending above Des Joachims village for a mile to McConnell lake. These indicated sand, gravel and boulders to below grade in the marsh with the rock rising on either side of the gully.

Through McConnell's lake for the next 2½ miles, no borings were necessary as the raised water would require no excavation. For about a mile, however, through the head of the gully at Ferris bay, 21 borings were made which showed 1 to 7 feet of boulders and sand on rock above grade. This rock rose to 20 and as high as 54 feet above grade, then abruptly lowered, and only sand, boulders and gravel were encountered out through Ferris bay to the main river.

From mile 271 to 277½ owing to deep water, no borings were necessary. At Reilly's rapids, between mile 277½ and 278½, no borings were taken as solid rock is in evidence on the surface of the small islands and shoals, and along the shore.

From mile 278½ to 279½, owing to deep water, no borings were necessary.

At McSorley's rapids, between mile 279½ and 280½, the small islands and shoals show solid rock at surface.

From mile 280½ to the Maribeau rapids, mile 282½, owing to deep water, no borings were taken.

The characteristic feature of this part of the Ottawa river and of the Nipissing district is the prevalence of considerable boulder drift formation on the surface, and also extending to a great depth in some localities, which necessitated an investigation by test pits.

Between mile 282 and 283, an investigation was made for a dam site across Maribeau island and on both shores. Five borings were taken which showed 10 to 20 feet of sand, gravel and boulders on gneiss rock. This site was abandoned later and another site chosen further up the river. No borings were taken in the Maribeau rapids, as solid rock is in evidence in the bed of the river 3 to 7 feet above grade.

At the bend in the river below the Rocher Capitaine rapids, the line leaves the river and follows a depression across a projection of the north shore, thence entering the river again at mile 285¾. Fifteen test pits and borings were made here during October and November, 1906.

At the approach to the Rocher Capitaine locks, the investigation showed gneiss rock 2 to 22 feet above grade, elevation 390 to 410.

ROCHER CAPITAINE REACH.

During 1906, an investigation was made at mile 284 for the proposed locks. Seven borings and test pits were made. At the lower lock, the investigation showed 3 to 5 feet of boulders and gravel on gneiss rock, 40 to 60 feet above grade. elevation 428 to 448. At the upper lock, the borings showed 1 to 4 feet of muck and loose rock on gneiss rock 38 to 44 feet above grade, elevation 456 to 462. Above the locks for a distance of 3,000 feet, the borings showed 12 to 15 feet of muck and fine gravel on gneiss rock 5 feet above grade; for the next 2,500 feet, the test pits showed 10 to 15 feet of boulders and gravel on gneiss rock 20 to 36 feet above grade, elevation 468 to 484; and for the next 3,600 feet to the river, the investigation showed 2 to 12 feet of boulders, gravel and sand on gneiss rock, from 1 to 17 feet above grade, elevation 449 to 465.

At the chosen dam sites which cross both branches of the river to the Rocher Capitaine island, 5 test pits were made. The investigation over the main channel showed solid rock at surface on the north shore, and on the south shore, two test pits showed 12 to 20 feet of hardpan which was not penetrated to the solid rock, being considered hard enough for the purpose. For the dam over the back channel, 3 test pits were made showing 3 to 15 feet of boulders, sand and hardpan, which was not penetrated to solid rock.

From the head of Rocher Capitaine rapids, mile 286 to the foot of the Deux Rivières rapids, mile 296½, no borings were taken, owing to deep water throughout.

DEUX RIVIERES REACH.

At the foot of the Deux Rivières rapids, the line leaves the river and follows up a slight depression of the Deux Rivières creek, joining the river again at the head of the Trou rapids. Thirteen borings and test pits were taken here during November, 1906.

At the approach to the Deux Rivières lock, the investigation showed gneiss rock at surface 15 to 30 feet above grade, elevation 463 to 478.

At the proposed lock site, borings showed about 1 foot of sand on solid rock 37 feet above grade.

For about 2,500 feet above the lock, the test pits showed about 5 feet of muck, gravel and boulders to below grade. For the next 3,500 feet, the investigation showed 5 to 12 feet of boulders, gravel and sand on rock 2 to 6 feet above grade. And from there to deep water, showed muck, sand and gravel to below grade.

At the proposed dam site, the investigation showed solid rock at surface on the north shore, one boring on the south shore showed about 20 feet of boulders, gravel and sand, and another showed rock at surface; in the bed of the river, the investigation showed considerable deposit of boulders, gravel and sand.

DEUX RIVIERES REACH. (ALTERNATIVE.)

During January and February 1906, an alternative route was investigated for a lock, canal and dam, about 1,000 feet north of the chosen route. Twenty-four test pits and borings were made here, a total of 422 feet. At the approach to the proposed lock site, the investigation showed boulders, gravel and sand to grade.

At the proposed lock site, mile 296½ the test pits showed boulders, gravel and sand to 10 feet below grade, but no rock was encountered.

Above the lock for a distance of 7,500 feet, the test pits and borings showed 5 to 45 feet of boulders and sand to below grade.

At the proposed dam site, the investigation showed gneiss rock at surface on both sides of the river; and in the bed of the river, boulders, gravel and sand on rock. From mile 298 to 309, owing to deep water, no borings were necessary.

Between miles 309 and 313, several small shoals 2 to 4 feet above grade, showed boulders and gravel.

From mile 313 to 317 in deep water.

From mile 317 to the foot of the Mattawa lock, the investigation showed boulders, gravel and sand to grade.

MATTAWA REACH.

Between the Ottawa and Mattawa rivers at Mattawa village, an investigation was made during May and December 1905, for a lock and canal. Eighteen borings and test pits were taken through the natural depression back of the village.

At the approach to the lock, the test pits showed about 10 feet of sand and gravel, on boulders and gravel, to 10 feet above grade. This material could not be penetrated to grade owing to the water from river flowing into test pits; the same trouble was encountered at lock site; consequently grade was not reached, but the material penetrated showed sand, gravel and boulders to about 6 feet above grade.

From the head of the lock to the Mattawa river, the borings showed boulders on gravel, sand and clay to below grade.

For the dam, 5 test pits were made which showed boulders on gravel to a depth of 24 feet.

From mile 319 to 320½, foot of Plain Chant lock, no borings were made, the surface material showing boulders, gravel and sand to grade.

PLAIN CHANT REACH.

In December, 1905, four borings were made for a dam site below the Plain Chant chute. Three of these borings showed 15 feet of boulders, sand and gravel; the other showed 8 feet of boulders and sand on rock; on the north side, no borings were made, rock being in evidence at surface.

In January 1908, another location for a dam was investigated further up the river, and borings taken on the north side showed rock at surface for about half the distance, the other half being covered with boulders, muck and sand for a depth of 2 to 10 feet.

At the Plain Chant lock, one boring was made which showed that the rock was covered with about 2 feet of boulders and sand.

Above the lock, granite rock is in evidence, at surface.

From mile 321½ to 326¾, Lake Plain Chant, no borings were taken.

LES EPINES REACH.

At Les Epines rapids, mile 326¾ to 327½, two lines were investigated for a lock and canal. Nine test pits were made, all of which showed a hardpan of boulders and sand to a depth of about 20 feet on loose drift sand to grade.

Above the proposed lock, the test pits showed hardpan to below grade.

Three dam sites were investigated:—1st, one below the rapids, 2nd, one at the foot of the proposed lock, 3rd, one at the head of the proposed lock. The test pits on the north shore showed the same material as was encountered at the lock site, but on the south side, gravel was found to a depth of 15 feet. At site No. 1 and at sites Nos. 2 and 3, rock shows up at surface, on the south side.

Between mile 327½ and 331½, no borings were made, the excavation necessary being very slight, and boulders and gravel are seen at the surface.

PARESSEUX REACH.

Between mile 331½ and 335, a short line to connect the Mattawa river with Lake Talon was investigated during September 1905. Seventy-three borings and test pits were made for canal and locks.

At the approach to the Lower Paresseux locks, solid gneiss rock shows at surface, and at both lock sites, rock shows up at surface, except in the bottom of the gully where about 15 feet of muck and sand overlies the solid rock.

Between the lower and upper locks, a distance of about 6,000 feet, the borings showed considerable muck, and sand on rock, in some places as much as 18 feet deep, which would be below the proposed grade line.

SUMMIT LEVEL.

At the Upper Paresseux locks, solid rock shows up at surface.

From above the locks to Beaver lake, a distance of about 2,500 feet, the surface shows solid rock.

From Beaver lake to Lake Talon, a distance of 3,000 feet, the borings and test pits show gravel and boulders and hardpan to below grade for about half the distance. The balance shows solid rock at surface, or a few feet below surface.

Between mile 334½ and mile 341, Lake Talon, no borings were necessary, as raised water gives the necessary draft.

Between Lake Talon and Turtle lake three routes were investigated.First, via McCool's bay to Pine and Pine to Turtle. Second, via Spottswood bay to Pine and Pine to Turtle. Third, Mattawan river and through a chain of four lakes and ponds to Turtle lake.

On route No. 1, eighteen borings and test pits were made during July and August 1905, showing boulders, gravel and sand to grade, to a depth of 55 feet in one hole.

On route No. 2, 32 borings were made during August, 1905, showing boulders and hardpan at east end, and in swamp, muck sand on boulders and bed rock above grade.

On route No. 3, 52 borings were made during January, 1905 and April, 1906, showing sand and clay to below grade, except points of land which show boulders on top where no borings were made.

In Pine lake, 95 borings were made in February, 1905, showing mud and sand and boulders and rock above grade.

Between Pine and Turtle lakes, 13 borings were made in August, 1905, showing boulders and sand on bed rock at east end, and muck and sand on bed rock at west end.

In January, 1905, 120 borings were made in Turtle lake as follows: In the east end 20 borings made showed mud and gravel to below grade.

At the head of the Mattawan river, 19 borings were made which showed sand and gravel to below grade.

Between mile 345 and 346½, 81 borings were made showing sand and gravel to below grade, and bed rock at the points of land.

In January, 1905, 120 borings were made in Trout lake as follows:—

Between miles 374¼ and 349, 74 borings were made showing mud and gravel to below grade, except at points.

At mile 350, 8 borings were made showing mud and gravel below grade.

Between mile 350 and 355½ no borings were necesary owing to the depth of the water in the lake.

At the head of Trout lake, 38 borings were made showing sand and gravel to below grade, these borings being for an alternate route.

Between Trout lake and Nipissing lake, mile 355½ to 359½, 185 borings were made in March and June, 1905, and November, 1906, 50 of these being taken in a chain of 5 small lakes, as follows:

Between Trout lake and McLean lake, 11 borings showed sand, gravel and boulders on rock considerably above grade.

Between the other small lakes along the canal line west of Trout lake, borings showed boulders, gravel and sand on bed rock.

In the bed of the above several lakes, borings showed mud and gravel on rock below grade.

Between the last lake and head of lock, borings showed sand, and gravel to below grade.

At the lock site, 12 borings were made showing sand, and sand and gravel on rock above grade.

From the lock, mile 358, to Lake Nipissing, 2 lines of borings were made and 87 borings taken, showing sand, and sand and clay to below grade, 35 feet deep, except at mile 358½, where bed rock was in evidence above grade for 1,200 feet, also at mile 359.

In Lake Nipissing, no borings were made, except at Rocky Point. Tests, however, were made by survey party and showed sand and gravel to below grade.

FEEDER. (SECTION NO. 1).

During October and November, 1906, a line was investigated for a canal to feed Lake Talon with water from a number of lakes in Algonquin Park via the Amable du Fond river and across to Sparks creek.

Sixty-three borings were made over the proposed centre line of canal which showed boulders and sand on bed rock over a considerable part of the route; solid rock is in evidence at surface in many places along the side hills where followed.

Fifteen borings were made at the proposed dam site over the Amable du Ford river on both sides of the river bed, where bed rock is encountered a few feet below surface, the borings in the bed of the river show 5 to 10 feet of sand and gravel on bed rock.

A total of 432 feet of borings were made. (For further details, see Boring Book, No. 39.)

AMABLE DU FOND ROUTE. (ALTERNATIVE.)

From Lake Plain Chant to Talon lake, considerable investigation was made via Amable du Fond route during October, November and December, 1905; commencing in Lake Plain Chant, mile 325, connecting a chain of 7 lakes and part of the Amable du Fond with Pimisi bay, the Mattawa river and Lake Talon, mile 335, 14 localities for canal and dam were investigated, and 144 borings made. Details of these borings are to be found in boring books, Nos. 38 and 10.

At the Little Paresseux falls, two sites for a dam were investigated, in October, November and December, 1905, over the upper sites, 7 borings were made showing bed rock a few feet below grade, and over the lower site, 4 borings were made showing boulders, gravel and sand to a considerable depth.

Canadian Pacific Railway Diversion, necesary in case of Amable du Fond route.

A diversion line for the Canadian Pacific Railway was investigated November 15-18, 1905, and 18 borings were made. Solid rock was in evidence at surface over a considerable part of the line, the balance showing sand and clay to a considerable depth on bed rock.

FRENCH RIVER.

No borings were made on the French river. Solid granite rock is in evidence everywhere.

SUMMARY OF TEST BORINGS.

The total number of borings plotted on plans, made on each section, is as follows:—

Section No. 9.—Montreal to Ste. Anne (including Rivière des Prairies)	349
" 8.—Ste. Anne to Carillon	302
" 7.—Carillon to Ottawa	232
" 6.—Ottawa to Chats Falls	170
" 5.—Chats Falls to Coulonge	178
Calumet Channel	82
Culbute Channel	13
" 4.—Coulonge to Des Joachims	198
" 3.—Des Joachims to Mattawa	62
Amable du Fond	144
C. P. R. Diversion	18
" 2.—Mattawa to Talon lake	123
Feeder and Dam	78
" 1.—Talon lake to Lake Nipissing	635
	2,584
Borings not plotted on plans	406
	2,990

Feet bored, 27,000.

APPENDIX C.

LOCK GATES.

Office of Henry Goldmark,
Consulting Engineer,
216 Board of Trade Building,
Montreal, December 20, 1906.

A. St. Laurent, Esq.,
Asst. Chief Engineer,
Dept. of Public Works,
In charge Surveys, Georgian Bay Ship Canal,
Ottawa, Ont.

Dear Sir,—As requested by you, I have gone over carefully the estimates of weights for the lock gates of the proposed Georgian Bay Canal, kindly sent me, and find them to be correct. The width, depth and lifts are in accordance with the list of locks furnished to me from your office, which I beg to return herewith.

These gates are of the mitering type, with outlines and proportions in accordance generally with the sketches sent you with this letter. They are to be built of medium steel with timber meeting pieces at the sill as well as the hollow quoins and the miter posts. The rise of the gates is, in every case, one-fifth of the span between quoin centres. A brief description of their construction is given in a subsequent section of this letter.

As the report you are preparing is, I understand, for purposes of estimate only, no attempt was made to design the details of the gates, nor to prepare working drawings for the specific dimensions of the several locks.

The estimates of weights as computed in the accompanying tables are, however. based on the extended series of designs made by myself for the United States Board of Engineers on Deep Waterways in 1897-99.

These designs and studies covered a large number of gates for locks 60, 65 and 80 feet wide in the clear, for depths on sill of 21 and 30 feet, and for lifts as high as 50 feet. In each case the stresses were computed, the cross-sections of steel, in the different parts, laid out from merchantable sizes of metal, and the weights calculated for variations of three feet in the lifts of the lock. Upper gates and guard gates were also designed in detail.

The results of these computations, which included the proportioning of many hundreds of gates, were used as the basis of general formulae, giving the total shipping weights of the gates in terms of the dimensions of the gates.

These formulae appear to give satisfactory results, even for locks much wider than those on which they were based. On substituting the dimensions of the 100 foot Poe lock at Sault Ste. Marie results were obtained for the calculated weights, differing only about 6½ per cent from the actual shipping weights of these gates.

As the dimensions of the Georgian Bay Canal agree quite closely with those used in the designs on which the formulae were based, I feel entirely confident that the results obtained from the general equations will give satisfactory results agreeing quite closely with the actual weights of the gates. In other words, it may be considered certain that good substantial gates can be built, which will not weigh more than the amounts given. To cover contingencies and differences of opinion in future designers it is recommended to add say ten per cent to these weights. It may perhaps be de-

sirable to give briefly the conditions as to loading and stresses under which these gates were calculated.

The general shape of the gate is practically straight in horizontal outline, only the upstream side being slightly rounded near the ends. This shape for locks 65 feet wide gives a better and more economical construction than the arched or curved forms, besides having many practical advantages in operation.

As stated above, the clear lock width is 65 feet, the depth on the sill is 22 feet to normal water level and the lifts vary from 12 to 44 feet.

The top of the coping on the lock walls is taken at 5 feet above the normal water level, the top of the gate proper being one foot below top of coping. All computations were made with the water extending to the top of the gate, or four feet above normal water level.

The gates are single skin gates, the plating being put on the upper side. The lower side has no plating, but merely sufficient bracing to maintain the shape of the gate. This enables all parts to be examined without difficulty, and to be readily cleaned and painted.

The *horizontal* type of construction was adopted throughout. There is a series of horizontal girders which are spaced about 3 feet apart and serve to carry the water pressure to the hollow quoins in the side walls. Between these girders a series of upright vertical frames are placed to ensure ample stiffness against accidental blows and to maintain the proper shape of the gates. The presence of such vertical stiffening frames, although essential to the proper construction of the gates, render the exact distribution of the stresses over the different horizontal and vertical members somewhat uncertain. In designing the typical gates mentioned above, the rule was followed of computing every part of the gate for the heaviest load that could come upon it under the most unfavourable supposition. This method gives gates that must be amply strong to resist the water pressure, while at the same time additional strength is supplied near the top of the gate which is most liable to accidental injury.

Under the above severe conditions, no part of the metal is stressed more than 10,000 pounds per square inch.

Hoping that the data herewith given will be sufficient for the purpose of your Report.

I remain, very respectfully yours,

(Signed) HENRY GOLDMARK,
M. Can. Soc. C.E., M. Inst. C.E.

NOTE—For types of gates refer to plates 32 and 33.

EXTRACT OF REPORT ON LOCK GATES.

(U. S. DEEP WATERWAY COMMISSION—1900.)

As a preparation for the design of the gates, the plans of many existing large locks were carefully studied and the literature upon the subject, both in English and in foreign languages was made the subject of an extended research. A list of the authorities consulted upon the subject of mitering gates is given at the end of this report, with a brief note in regard to each. It is believed that the list is quite complete, covering nearly all that has been written upon the subject.

An investigation was made to determine whether some one of the numerous forms of single-leaf gate or the mitering gate is the more desirable type for the work in hand. The result was the adoption of the mitering gates as a basis of the designs and estimates.

A study was then made of the relative merits of the horizontal and vertical systems of framing for mitering gates, resulting in the adoption of the horizontal system.

Steel mitering gates of the horizontally framed type having been decided upon, a lengthy investigation was made to determine the rise of sill and the form, whether girder or arch, of horizontal frame which will give the best results when economy of construction and facility of operation are considered. The question of the relative economy of the arch and girder form of horizontal frame has been a mooted one for a long time. The result of the investigation was the adoption of a rise of sill of one-fifth the width of the lock for all cases, and the adoption of a horizontal frame straight on the downstream side and curved on the upstream side, with depths varying for different widths of lock.

This is the so-called girder type. It was found that it presents advantages of greater stiffness and requires a shallower recess in the side wall than the arch form, and that, considering the state of the labour and steel markets at the present time and during the last decade, it is actually cheaper.

For the quoin and miter posts, wooden-bearing pieces were used on gates having the lighter pressures, but it was found necesary to use metal in some of the gates for locks of very high lifts.

A study was made of the variation in the position of the centre of pressure at the miter and its influence in determining the most economical form of horizontal frame. The results of this study are given later.

The use of air chambers and rollers to reduce the reaction upon the anchorage and pivot was considered and rejected except in the case of gates weighing more than 500,000 lbs. per leaf, in which case the lower part of the gate is enclosed, but rollers have not been adopted even for these extreme conditions.

Although the gates are of the horizontally-framed type, there must necessarily be a few verticals. What the action of these verticals is, and what effect they have upon the distribution of loads between the horizontals, is a very complicated problem, and considerable time has been given to its solution by several different methods.

For the purpose of an estimate, a large number of gates were designed in detail and their weights carefully computed. The law of variation of weight of gates for different widths and lifts of lock and depth of water on sill was discovered and some general equations giving the weight of gates for any width of opening, depth of water on sill, and lift of lock within limits were derived.

The foregoing is a brief statement of the work done and the results obtained.

Following will be found under their proper heads, detailed discussions of the points mentioned above.

CHOICE OF TYPE.

Besides the ordinary double-leaf mitering gate, which has been used so long and so exclusively that it has become the standard form, there are numerous forms of single-leaf gate. The differences between these various forms depend entirely upon the method by which they are moved into and out of place.

The sliding gate moves endwise into a recess in the side wall of the lock. The lifting gate moves vertically upward, and the plunging gate vertically downward. The single-leaf swinging gates revolves about a vertical axis at one of its ends, and the quadrant gate about a vertical axis in the center line of the lock, at a distance from the gate of the half width of the lock. The tumble-gate revolves about a horizontal axis at its lower edge. The bascule gate revolves about a horizontal axis at one of its lower corners, operating like the bridge of the same name.

All the above forms of gate have been proposed and most of them have been used.

All forms of the single-leaf gates possess in common the advantage of allowing a somewhat clearer and more definite analysis to be made of their stresses than does the mitering gate, and also the advantage of allowing simpler operating machinery.

For the work in hand the lifting gate could not be used on account of the masted vessels which will use the locks.

The plunging gate is practically untried and presents serious difficulties in the problem of keeping clean the pit into which it descends, and in most cases the masonry would cost more than for mitering gates. A roller bearing similar to that used in the Stoney sluice gate is usually introduced, which gives the gate the advantage of being moved rapidly and operated under much greater head of water than the mitering gate.

The sliding gate has been used in numerous cases in Europe and presents many advantages, chief of which is its ease of movement, as it is pulled endwise, thus offering less resistance to the water than it would if moved in any other direction. In a tidal lock it is especially adaptable, since it will withstand a pressure from either side. The gate may move on trucks or rollers on its bottom, or it may be suspended from above and run upon a fixed or a swing bridge.

The single-leaf swinging gate possesses the merit of reliability and of easily analyzed stresses, but is not economical, is slow of movement, requires much more power to operate it, and when used for a lower gate it reduces greatly the effective length of the lock.

The tumble gate has the advantages of easily analysed stresses, simple masonry, and for low lifts it is quickly moved and is economical of masonry, but it requires a pit in the bottom of the lock which is not easily cleaned. It is more particularly adapted for upper gates in the case of high-lift locks. When used as a lower gate it decreases too much the effective length of the lock. It has been used abroad and upon the Erie canal in this country.

The advantages claimed for the quadrant gate are that it is quick of operation and gives a maximum effective length of lock with minimum cost of masonry. On the other hand, it is as yet untried, and, considered with respect to its stresses, it is unscientific, since its reactions on the side walls are in a direction to increase the bending movement upon the horizontal girders, and, unlike all other forms of single-leaf gates, its reaction has a component normal to the side wall.

The bascule gate has been hardly more than suggested. It has no apparent advantages over the other forms of gate.

Designs and careful estimates were made of single-leaf swinging gate, a single-leaf sliding gate, and a mitering gate, all for the same location, and it was found that they did not differ materially in weight.

The form of gate which would actually cost least will not be the same in different cases, but will vary with the width and depth of opening and lift of lock and with local conditions, but the difference of cost between any two of these forms of gate will not be great.

Speed of operation, reliability and immunity from accident are more important considerations than first cost.

The mitering gate has stood the most rigid test, the test of time, and is practically the standard form of gate for locks. Its use shows no sign of abatement and as all forms of single-leaf gates are more or less untried for large locks, it was deemed best to make the mitering gate the basis of estimate for the present work.

MATERIAL.

The choice of material for the gates lay between wood and steel.

Wood has been used almost exclusively for small gates and for large gates it has its full share of favour. In this country, where timber is abundant, it has been used and has given excellent satisfaction, but like the wooden bridge, its use is on the decline and the more recent large gates have been built of steel.

In England, however, although timber for gates has to be imported it is still used quite as much as steel ,even for the largest gates. A case in hand is the Manchester Ship canal, which has all its gates built of green heart timber.

The advantages of timber for gates are its lightness when submerged, its ease of repair in case of accident, and in many localities its low first cost. On the other hand the life of a timber gate is comparatively short. It begins usually to show weakness after from 10 to 15 years, involving repairs and requiring to be renewed after from 15 to 20 years.

Steel for gates is more in favour than wood in this country, and is preferred about equally in England, while on the continent of Europe it is used exclusively.

When designed to admit of inspection and painting, steel gates are much more enduring. Some of the early examples show little rusting after 30 years.

The chance of accident is not believed to be great enough to warrant the use of wood on account of its repair. In many of the proposed locks for the deep waterways, the lift is so great that it would be almost impossible to provide the necessary strength in a wooden gate. For these reasons, and because steel is structurally, a much better material than wood, steel gates have been designed for all the locks.

RISE OF SILL.

The principal functions of the two leaves of the mitering gate when closed is to form an arch, which takes the water pressure and transfers it to the side walls.

What the rise of this arch shall be is a question of some importance. The weight of the gate depends somewhat upon the rise of sill, but only to a slight extent. There are more important practical considerations which decide the question.

The less the rise of sill the longer will be the time required to open and close the gate, and the greater will be the thrust upon the masonry and the effect of any change in the length of the gate due to change of temperature. On the other hand the greater the rise of sill the longer the gate and consequently the shorter the effective length of the lock, and if the gate be economically designed, the deeper will be the gate and gate recesses.

The choice of rise of sill then, becomes a compromise between the above advantaages and disadvantages. Inasmuch as a rise of one-fifth the width of lock seems to best satisfy the practical considerations and also to require a somewhat lighter gate than any other, it has been used for all the gates designed.

AIR CHAMBERS.

If the gate is not otherwise supported the pivot must carry the total weight of the gate less whatever flotation it may have, and, besides both pivot and upper hinge sustain horizontal reactions of considerable magnitude.

Two methods have been followed to relieve the pivot upper hinge.

The first is to place under the gate a roller, which runs upon a track in the bottom of the lock, and carries part of the weight of the gate. This device has been used with timber gates quite extensively, especially in England, but the custom is being discontinued. In order that the rollers shall work perfectly the axis of rotation of the gate must be perpendicular to the plane of the roller's track. Any inexactness in this plane or settling of the track may make the roller useless. Wearing of the roller-bearing may do the same.

The second method of reducing the reactions of the upper hinge pivot is to place a water tight sheathing on both sides of the gate, forming an air chamber, which supports the gate by buoyancy. This method is quite generally used. It has, however, many serious disadvantages. As gates with sheathing in both sides have usually been built, their interiors have been very difficult to inspect, clean and paint, on account of the too confined space for efficient work and especially the difficulty of ventilation while painting. The result has been that many enclosed gates have been left without painting of their interior during their entire life, which was materially shortened thereby.

The gates sheathed on both sides are more expensive because the shop work and assembling of parts is more difficult; there are more joints to calk and the calking of joints must be done with greater care, and because the extra sheathing, especially when horizontal frames straight on the downstream side are used, adds weight and little or no strength.

The pivot and upper hinge must be made strong enough to sustain the reaction of the gate when it is swung in air at times when the lock is pumped out, therefore the pivot can not be made much smaller when double sheathing is used than when it is not.

It would seem that the gate with a single sheathing is preferable in every way, provided the pivot is not overstrained and its size is not impracticable.

All the gates designed, with the exception of a single case, have, as the drawings show, sheathing on one side only, leaving the interior open and allowing of inspection and painting at all times. This results in a very simple construction, which will cost little more than ordinary bridge work.

QUOIN POST.

The function of the quoin post is fourfold. It must act as a column in carrying the weight of the gate; it must act as a girder transversely to the gate and also in the plane of the lines of thrust of the horizontal frames and distribute the pressure along the quoin; and withal it must furnish a satisfactory closure between the gate and wall.

The post as designed consists of a very thick web plate with four heavy flange angles. This forms the vertical girder acting transversely to the gate. To the flanges of this girder and lapping well upon the horizontal frames are riveted a heavy 36-inch plate on the up-stream side and a 42-inch plate on the down-stream side, which distribute the thrust of the horizontal frames.

It is deemed advisable to make the bearing pieces of the quoin posts of wood, except in the heaviest gates, where metal is used. In most of the gates designed the thrust in the quoin is so great that the required bearing area demanded by the masonry is very large. A large bearing can be provided much more cheaply and satisfactory by the use of wood than by steel for the bearing part of the post.

Wood is easily shaped. It adjusts itself to any unevenness of errors of workmanship and is more easily repaired or replaced in case of accident or wear.

The axis of rotation has 1 inch eccentricity from the center of the cylinder. Thus the wood is relieved from bearing as soon as the gate begins to be opened. The eccentricity being small, there is very little chance for any foreign substance to lodge between the wood and masonry.

From the consideration of the quoin itself the cylindrical form has every advantage. Much greater width of bearing can be provided by its use than with the flat form, since the width of the flat bearing is limited by the consideration that the center of rotation must lie on the upstream side of a perpendicular to the bearing plane erected at its upstream edge. The principal advantage, however, of the cylindrical bearing piece is the fact that the line of thrust must always pass through the center of curvature, while with a flat bearing piece the position of the line of thrust will always be in doubt, the only sure thing about it being that it has considerable variation, reducing the allowable average intensity of pressure upon the surface and causing an uncertainty and variation of the stresses in the horizontal frames.

In cases where the pressure per vertical inch of quoin does not exceed 9,000 pounds, it is proposed to use wood in the quoin post. As the width of bearing is 23 inches, the greatest intensity of pressure amounts to about 400 pounds per square inch between the wood and the stone.

In some of the gates designed the thrust at the quoin passes this limit, as it was not thought practicable to make the timber bearing wider than 23 inches. A metal

quoin and metal bearing pieces on the quoin post are used for these heavy pressures.

The post itself is the same as before, except the steel-casting bearing pieces.

This metal quoin is intended for use on all heavy gates sixty-five foot locks, which withstand a head of more than 40 feet.

All the castings are of steel. No eccentricity is used, as in the case of wooden bearing pieces, the quoin and quoin post being in contact at all times. This eliminates all danger of foreign substances lodging between the bearing surfaces. It may appear at first sight that this arrangement will cause a large frictional resistance in the quoin. The resistances will not be much greater without than with eccentricity in the quoin, since the horizontal thrust, due to the weight of the gate, must be taken care of either in the quoin itself or concentrated upon a bearing at the bottom of the gate. The lever arm of the frictional resistance of this bearing for the very heavy gates could not be made much shorter than the radius of the quoin, and, as friction is independent of area, little would be gained and much lost by providing an eccentric bearing.

The only gain would be the slight reduction of the horizontal thrust of the gate while turning, on account of the slightly lower position of its center of resistance and the fact that the smaller bearing would keep cleaner and have a somewhat lower coefficient of friction. However, even assuming a very high coefficient of friction less than one-half horse-power will be required to do the work of overcoming friction in the heaviest gate.

MITER POST.

The functions of the miter post are practically the same as those of the quoin post, the only difference being that it bears against another similar post instead of against a hollow quoin and does not carry the weight of the gate. As designed it is structurally the same, the only difference being in the shape of the bearing pieces, which are of the same material in the quoin and miter post in all gates.

Details of the posts with timber bearing pieces are shown on plan. The drawings explain themselves without further description; where timber is shown it is proposed to use white oak.

The practice in the past has been to use wood exclusively for the meeting faces of the gate. In a few of the more modern gates, however, steel is used. Wood has been preferred to steel because it makes a more water-tight joint on account of its more yielding nature. This is certainly true in cases where the thrust of the gate is not great. It is probable, however, that if the intensity of pressure between the steel bearing pieces be high and the parts carefully made, a very good joint will result. In the present work, the use of steel bearing blocks in some cases would be imperative, since the thrusts are so great as to require a bearing 3 feet wide if of timber,

Considerable time has been given to the study of the position of the centre of pressure at the meeting faces, since upon it depends quite largely the stresses in the horizontal frames.

The meeting faces made be made plane or curved. The former is the more usual shape and is entirely satisfactory when the thrusts are moderate enough to allow of a comparatively narrow bearing face being used; but when very wide bearing is required, plane meeting faces give trouble by 'nipping' or meeting at their extreme edges. If the faces of the bearing pieces are planes, the most favourable condition is a uniform pressure over their entire surface.

This ideal condition cannot be realized in practice, as it can only occur for one definite length of the gate leaves, and then only if the angle at which the meeting pieces are fitted is absolutely correct.

Since the length of the gate varies with the temperature and the stress to which the structure is subjected, and, furthermore, absolute exactness either in the shape

of the gate or the fitting of the miter pieces is impossible, a strictly uniform pressure will never occur.

When gates are being closed and the two leaves approach each other, the bearing pieces will first meet on their extreme upstream or downstream edges, the faces making a very small angle with each other.

As the water pressure comes upon the gate the material compresses, and from being in contact at a line along the extreme edge they come in contact along a vertical strip extending from the edge of the meeting faces toward their middle, and in most cases bringing their entire surface into contact.

If the designer is convinced that the bearing blocks will be thoroughly saturated at all times, and if he will proportion them so that the pressure per vertical inch of miter, divided by the width of the bearing face in inches shall be about 400, he may use bearing blocks with plane meeting faces with little fear that the centre of pressure will be more than, say a tenth the width of face from its centre. If he is not sure of this, he must make whatever assumptions seem to him reasonable.

By giving the bearing blocks a cylindrical form of large radius, there will be much greater certainty that the range of the centre of pressure will be confined to narrower limits.

The practice of those in charge of locks bears out the wisdom of this. It is their custom, when the gates give trouble by nipping, to slightly round the faces of the bearing blocks, which expedient has been found to remove the trouble.

STEEL BEARING PIECES.

Very much more favourable conditions as regards eccentricity of pressure prevail when steel bearing blocks are used in the quoin and miter posts. Very little uncertainty exists in regard to the position of the centre of pressure, and it is quite certain that its variation will be small.

FRAMING.

Since the two leaves of the gate form an arch which receives the horizontal load of the water pressure and transmits it to the side walls, it necessarily follows that the principal members of the gates must be horizontal frames extending from miter to quoin post. These horizontals may be placed so close together that the sheathing is able to deliver the water pressure directly to them, or they may be placed farther apart and vertical girders employed to take the pressure from the sheathing and deliver it to them.

These two arrangements divide gates into two classes, known as the horizontal and vertical types, the relative merits of which have been made the subject of much discussion.

An extreme case of vertical framing is the use of but one horizontal, and that at the top of the gate, allowing the lower end of the verticals to bear against the sill. This has the advantage of allowing a very clear analysis of the stresses in the verticals and making the sill do much of the work that would otherwise be done by the horizontals. This form of gate may be economical under small heads of water and in gates that have much greater length than height. A difficulty arises, however, in providing a satisfactory detail at the miter and quoin posts.

Between this extreme case and the purely horizontally framed type there is the case of relatively few horizontals with intermediate verticals. A satisfactory detail at the miter is possible with this arrangement, and it has a field in which it may be used with economy. This field includes cases of very low lift of lock in which the pressures are small. This type may be used with economy for upper and lower gates for 60 foot locks having lifts less than 8 or 10 feet.

These cases are very rare, however, in the locks for the proposed waterway, and all the designs are the purely horizontal type of framing.

HORIZONTAL FRAMES.

One of the questions in gate design most frequently discussed is—What shall be the shape of the gate in plan, i.e., what is the proper form of the horizontal frames?

A circular arch form is advocated quite generally, on the ground that for the same strength it is lighter and is therefore cheaper. A sort of gothic arch is preferred by some engineers, and still others advocate the so-called girder form, which is straight on the downstream side and any desirable shape on the other. The advocates of this latter form maintain that it has many inherent advantages over any other and that when properly designed its weight will be but little greater than the arch form, and that, owing to its greater simplicity, its low cost of construction will make it as cheap or cheaper.

The considerations which should decide the form of horizontal frame are the following:—

It is very desirable that the gate recesses in the lock walls should be as shallow as possible. This is a decided point in favour of the so-called girder shape.

It is also considered desirable that when the gates are open and in their recesses they should continue the line of the wall; in other words, be straight on the downstream side.

The gate should be as stiff and as rigid as possible against unavoidable accidental blows and rough usage to which it will be subjected. The arch, being comparatively thin, is notably weak in this respect.

For the work in hand it is especially desirable, for reasons which have already been discussed, to use a single skin gate.

Consequently it is desirable that the gate should be straight on the downstream side, to allow of diagonal bracing.

Lastly, there is the question of economy. In the face of the above disadvantages, however, it would seem that the arch form must show very much greater economy in order to be perferred to the gate straight on the downstream side.

The cost of a structure is made up of two elements—cost of material and cost of workmanship.

The cost of material depends upon conditions over which the designer has no control. The cost of workmanship depends quite largely upon the character of the design. The amount of material which may be used to save cost of workmanship depends upon the relative cost of the two. This relation has continually changed, and any deductions based upon it at one time will not necessarily apply at another.

As the cost of material increases, the greater will become the relative economy of simple structures. In general, the so-called girder shape will be simpler than the arch and make the gate cost less per pound.

If the line connecting the centers of gravity of different sections of a horizontal frame coincides with the line of thrust, then it will be a perfect arch without transverse stress. If this arch has a rise conducive to economy, there is little doubt that so long as this ideal condition of exact coincidence of centre of thrust and centre of gravity exists, the minimum amount of material will be required for the frame.

The circular arch can be readily made to fit this condition for one position of the line of thrust, but the line of thrust must pass through the centre of pressure at the miter, and, as has been seen in the study of the miter, the position of this centre of pressure varies between rather wide limits, depending upon the construction of the bearing blocks. Any deviation of the line of thrust from the line of centre of gravity introduces cross bending in the arch, which is not well shaped to withstand it, thus requiring a certain additional amount of material to resist bending.

The frame straight on the downstream side, though usually heavier when proportioned for a single position of the line of thrust, requires, on account of its greater depth, a smaller addition of material to cover the effect of bending.

It would seem that the arch form of horizontal frame will be the lighter if the miter can be so arranged that there will be no variation in the position of the centre of the pressure, and that it shows less and less economy as the variation increases until, if the eccentricity becomes great enough, the girder shape will be the lighter, always supposing that it has the greater depth, which in general will be the case.

This conclusion is borne out by mathematical investigation.

Besides the question of the relative economy of the two general forms of horizontal frame, there is the question of the proper rise of sill and depth for each.

It was recognized that a mere mathematical analysis is not sufficient to determine the form most economical of material, since in practice with the ordinary forms of roll steel it is not possible to make a theoretically perfect distribution of material.

The arches are somewhat lighter for all lifts, but the lightest gates for different rises of sill do not differ greatly in weight. In other words, the rise of sill does not cut much figure.

The saving in material by the use of the arch is in all cases less than 10 per cent of the weight of the gate, which is believed to be sufficient to warrant its adoption in the face of the great practical advantages of a gate straight on the downstream side. It is thought that difficulties in the construction of the arch will make the unit price enough higher to make up for the small difference in weight.

It was also decided that a rise of sill of one-fifth the width of the lock is most desirable for practical reasons, and that a certain amount of the sheathing should be considered as acting as a part of the horizontal.

The deductions from the results obtained are:—

First.—If the gate be designed for small variation of center of pressure at the miter, the arch will be the lightest form for the same strength.

Second.—The economy of the arch becomes less if A be increased until if E be taken great enough the girder form will be lighter, always supposing that it is the deeper, which in general would be the case.

Just how great E will have to be for the arch to be the heavier will depend upon width and lift of lock and relation of the thickness of the two forms of gate. In other words, as E increases a point will be reached at which the thicker gate, whether it is the arch or girder, will be the lighter for the same strength.

Third.—The arch formed of horizontal frames gives relatively greater economy in double skin than in single skin gates.

Fourth.—In single skin gates, if the variation of the centre of pressure at the miter be 4 or 5 inches more on each side of the centre of the bearing, the economy in material shown by the arch is certainly not great enough to overbalance the great inherent advantages of the gate straight on the downstream side and probably not great enough to make it the cheaper form in the present condition of the steel market.

A careful weighing of all the practical considerations and the conclusions of the investigations in regard to economy resulted in the adoption of the girder-shape of horizontal frames.

It will be noticed that the frame is perfectly symmetrical about its middle.

It is so shaped that the centres of the bearing faces, both in the quoin and miter posts, are placed well downstream. A line joining the centres of the faces of the bearing pieces in quoin and miter only lies 5½ inches away from the outside edge of the downstream flange—a very favourable arrangement.

It is believed that the frames have been so designed that the shop work and erection will be very easily and cheaply done.

PROPORTIONING OF HORIZONTAL FRAMES.

The direct load due to water pressure on any part of the gate is very easily found, since the intensity of pressure at any point is directly proportional to the head of water at that point.

The loads on the horizontal frames are not the same as the external loads of water pressure, for the reason that the vertical stiffness of the gate causes a redistribution of the loads.

The principal effect of this redistribution is to throw an increase of load into the upper part of the gate.

The increase of strength in the upper part of the gate is on account of the effect of the vertical stiffness and because it seemed best not to place the horizontal frames farther apart than they are and to use no lighter than ⅜-inch metal in their construction.

The lower or downstream flange is relatively light, and consists of two angles reinforced at their ends.

The section required for the up-stream flange is in most cases large. It consists of two heavy angles, a certain amount of sheathing, and a cover plate, which acts also as a splice plate for the sheathing.

What part the sheathing plates play in resisting flange strain is in doubt. Some designers neglect its action on account of the doubt and others would consider the entire sheathing as part of the flanges. The part of the sheathing plate which is connected to the flange angles must certainly act with the rest of the flange in resisting strain, since any change of length of the angles must cause a like change in that part of the plate which is attached to the angle.

The uncertainty lies in the inability to determine just how far away from the flange this action extends.

In the present work the flange section has been determined for the low unit stress of 10,000 pounds per square inch, and, when two 6-inch angles are used, a strip of sheathing 16 inches wide has been counted as part of the flange section, and when two 4-inch angles are used a strip of sheathing 12 inches wide was counted. The probability is that the sheathing has much greater effect than has been assumed, reducing the maximum stress, to, say 7,000 or 8,000 pounds per square inch. On the other hand, even should the sheathing not act at all the stress in the flanges would not be excessive.

SHEATHING.

The resistance of plates, supported at the edges, to forces normal to them is not well understood. No satisfactory theoretical analysis of their stresses has been made. The designer must rely upon empirical formulæ, derived from the results of experiment, to guide him in proportioning of sheathing plates.

The most recent well conducted series of experiments from large test plates are those of Prof. C. Bach, of Stuttgart.

From the results of these tests formulæ were derived which are probably the most reliable of any in use.

No plates less than ⅜ inch thick were used and none more than ½ inch thick were required. The sheathing plates are proportioned by the flat plate formulæ. although they are in reality curved and thereby derive considerable additional strength from arch action.

PIVOT.

The pivots are all of the same general design, although a difference is made in the shape of the castings in upper and lower gates on account of the difference in the sill contact.

The bearing is bronze upon polished steel. This combination has a low coefficient of friction, especially when working in water. The bearing parts move very slowly one upon another, the maximum rate of speed being only 0·02 feet per second.

A cast steel base embedded in the concrete floor of the locks holds the pivot proper, which is a steel forging hemispherical on top.

Bolted to the gate is another casting which holds a bronze bushing or hollow hemispherical cup which fits the pivot. The pivot is proportioned to take both the weight of the gate and the horizontal thrust.

UPPER HINGE.

As the height of the gate increases, the weight increases in nearly the same ratio, but the pull upon the upper hinge does not differ greatly between the lightest and the heaviest gates designed. For this reason little change is made in the anchor bars, and none at all in the castings for the different gates. The anchorage consists of eye-bars extending back in the masonry to beams embedded in the concrete. Sufficient masonry is embraced to preclude any danger of movement.

The angle between the anchor bars is slightly greater than that through which the gate swings, and they are so placed that both are always in tension, thus avoiding reversion of stress and the consequent danger of loosening and play of the parts.

Provision is made for adjustment by means of wedge-shaped keys.

The castings are of steel and proportioned for a very low unit stress. The anchor bars are also proportioned very liberally, to provide for any reduction of section which is likely to occur from rusting.

SILL CONTACT.

For the lower and intermediate gates the sill contact is made, by bolting to the flange of the lower horizontal frame a straight timber bearing piece which closes against a straight timber sill.

When the gates are closed a head of water equal to the difference of level of the two sides of the gate acts upon the bottom of the gate, tending to lift it. This lifting effort upon the lower gates is but slightly greater than the weight of the gates themselves, so that the friction of the quoin posts in the hollow quoins will overcome all tendency to upward movement. The coefficient of friction required to do this is only about 2 per cent.

On account of this upward pressure upon the bottom of the gate, numerous web stiffeners are placed upon the bottom frame, and its lower flange is strengthened by a plate extending to the flange of the frame above.

If the upper and guard gates and gates between locks of a flight should expose so great a bottom area as this to maximum water pressure, the upward lift would be far in excess of the weight of the gate. To meet this difficulty the bottom frame of these gates is made very much narrower than the others and no timber-bearing piece is used. Instead, the heavy steel flange angle is finished and bears against the sill.

The lower frame is attached to the one above at intervals by cast steel brackets.

A curved sill is required for these gates.

FOOT-BRIDGE.

For the convenience of the workmen and others a foot-bridge is provided upon the top of the gate.

It has a railing which is removable and built in short sections, so that one man can handle a section.

ESTIMATES.

In connection with the estimates, it is appropriate to review briefly the conditions which prevail in the structures.

The gates are of steel with horizontal framing. The spaces between the frames are variable, being 3 feet 3 inches near the top and less than 2 feet near the bottom of the highest gates.

The frames are straight on the down-stream side and curved on the other; their breadth is 4 feet in gates for 65 feet locks. They are proportioned under the assumption that the centre of pressure at the miter may have a range of position 8 inches each side of the centre of the bearing face. The maximum stress in the frames is 10,000 pounds per square inch. The maximum stress in the sheathing is 15,000 pounds per square inch. The minimum thickness of metal is 318 inches; the minimum angle used is $3\frac{1}{2}$ inches x $3\frac{1}{2}$ inches x $\frac{3}{8}$ inch. Diameter of rivets $\frac{7}{8}$ and $\frac{3}{4}$ inch.

NOTE.—The extracts forming this appendix are from a report by Mr. S. H. Woodard, C.E., prepared for the U. S. Board of Engineers on Deep Waterways and published in 1900. These investigations regarding steel lock gates were commenced by Mr. Henry Goldmark, C.E., and completed by Mr. Woodard.

Some of the details of gate pivots, hinges, etc., are shown on plates 32 and 33 accompanying this report.

APPENDIX D.

ELECTRICAL EQUIPMENT OF LOCKS.

OTTAWA, ONT., March 15, 1907.

Mr. A. ST. LAURENT,
Engineer in Charge,
Georgian Bay Ship Canal,
Ottawa, Ont.

DEAR SIR,—I have the honour to submit the following report in which I have gone into more extended explanation of the apparatus used than would ordinarily have obtained, had I not wished to make it particularly clear for the lay reader as well as for the technical reader. With this brief apology for its length, I may state, that, as directed by you, the work of preparing an estimate of the cost of electrical equipment for operating the locks, and the illumination of the locks, guide cribs and adjacent land lines for the Georgian Bay Ship Canal was begun January 8, 1907.

The instructions, which were fully detailed to me by Mr. S. J. Chapleau, M. Am. Soc., C.E., engineer in charge of the Nipissing district, called for as estimate of cost of a complete equipment including power-plant, electric power machines for operating lock gates and hydraulic valves and an interlocking or safety device for their inter-connection to insure the continuous operation of each lock or flight of locks individually. The instructions further embraced the use of direct constant potential of five hundred volts pressure, and embraced the further assumption that the maximum capacity of the canal would be reached at thirty-six lockages for twenty-four hours, as the controlling feature.

A careful study was then made of the local conditions at the site of each lock or flight of locks in the Nipissing district, following which a series of estimates were made in each case taking into account the various possible situations for a power-plant, allowable fall, quantity of water available, &c., &c.

The amount of power in units per hour was carefully determined by a schedule of the power for one lockage in H. P. per minute, which was reduced to ampere hours in twenty-four hours.

This schedule was arrived at by the calculation of the weights to be moved, or the pull to be exerted; the period of time during which such operation took place, and these in turn were compared with existing conditions and practice on other canals.

A determination was then made of the most economical and at the same time most efficient general scheme for power-supply. Next, a study was made of the various methods best adapted for the manipulation or operation of the gates and valves of the lock. Following this, a study of the best method of operation and control of the lighting circuits.

The lengths of the latter vary somewhat in each situation, but, as the variation is within $4,000 for the whole group, the method of averages, hereafter explained, was adopted.

When the estimates were completed for all the locks of the Nipissing district, the amounts of each part were summed up and an average struck to arrive at the round sum estimate for a single lock or for a flight of two locks tandem.

In this average, the single locks and flights were divided into the following parts:

(a) The generation of power.

(b) The electrical equipment for operating the lock.

(c) The electrical equipment for lighting the lock, its guide cribs and adjacent land-line.

(d) An estimate for an electrically driven outfit for unwatering the lock.

(e) An estimate for the operating machines for gates and valves.

A description of each of these parts follows:—

(a) The general scheme (with a single exception) of generating power, was by use of the fall of water around the lock, utilizing hydraulic turbines driving electrical generators of small power, which, in turn charged a storage battery of sufficient capacity to operate the lock at its maximum rate of thirty-six lockages in twenty-four hours, independently of the generating plant.

The introduction of the storage battery has been the result of investigation of current practice and experience on the more recent installations of European canals.

At Posen, Horin, Kliene-Machow, Mirowicz, Henrichenburg, Ymuiden and Munster, electricity is used to drive the operating machinery, and the arrangement most favoured by the engineers, and which is in use and has demonstrated its practicability, is the introduction of storage batteries or electrical accumulators of sufficient capacity to operate the lock for twenty-four to seventy-two hours. The dynamos under this method, are then run but a few hours, sufficient to fully charge the accumulators and, in case of accident to either, the other factor is used until repairs can be made.

This item embraces building and foundation, head-gates, screens, penstocks, turbine casings, draft tubes, over-head cranes, turbines, shafting, bearings, quills, generators, switch board and station wiring.

(b) The electrical equipment for operating the lock embraces the motors for the gates and valves, the interlocking devices for preventing accident due to carelessness or ignorance of the operators, the operating controllers, the switch boards in the operating cabins, the electrical storage batteries, the cabins, and all wires, cables, etc.

The motors for operating the gates were assumed to be five H. P. each, manipulated from the cabin by single reversible controllers.

This rating of five H. P. was adopted after a study of the conditions existing on other canals and hydraulic works. As example of the power of such a motor, at the Ontario Power Company's plant at Niagara Falls, Ontario, the sluice gate of the Stoney pattern, 18 ft. x 18 ft. under a head of 35 feet on the sill, is raised to its full opening under this difference of head in three minutes with a five H. P. motor. On the Soulanges canal, lock gates of upward of 70 tons are operated by five H. P. motors. On the Cornwall canal five H. P. motors are used for the same purpose, and were used in preference to three H. P. motors only on account of their slower speed.

On account of speed considerations, for uniformity of units and the negligible difference in cost, five H. P. motors are assumed for use on the gates and valves in this estimate.

The interlocking arrangement is provided by means of circuit-closing devices at each valve and gate machine, so arranged and electrically connected with the operating equipment at the opposite end of the lock, that an attempt on the part of one operator to open the gates or valves, while those or either of them at the other end of the lock are opened, would be useless. Moreover, each operator has, at his station, an automatic device which notifies him when the gates and valves at the other end of the lock are fully closed.

The interlocking outfit also embraces a device by means of which, when a gate or valve has reached its full travel, the electric current actuating the driving motor

is automatically reversed and cut out for further movement in the same direction, thereby preventing jamming. Another factor prevents straining of the motor or of the parts of the machine, due to obstruction before the mechanism has reached its full travel.

In a word, the object of the electrical device is to make the whole equipment 'fool proof.'

All wires and cables about the lock are designed to be conveyed in conduits of 3-inch tile pipe, embedded below the surface back of the lock wall. The wires for interlocking circuits and cables for power cross the lock, through the valve conduits in lead encased cables or in lead pipe through which renewals may be made by means of 'fishing.' These pipes terminate below the coping in suitable junction boxes.

The wires feeding the lamps on the lock are conveyed through these conduits and up inside the iron tubular poles from which the lamps are hung. This does away with the necessity for poles supporting wires between lamps or any other aerial wires about the lock.

The type of storage battery or accumulator estimated for was the chloride cell. Of these, there should be about 280 cells to each battery, which allows for end-cell regulation to the extent of about thirty cells, or for a fall of potential of about 60 volts.

The operating cabins are designed to be similar to what are known as 'block towers,' used on railways for interlocking and signalling plants. By this means the space in the lower story of one of the cabins may be used for the accumulators, while that of the other cabin may be used for store-room or a tool-room. The operator being in the second story, has, by means of ample window spacing, an unobstructed view over the whole lock and is sufficiently elevated to overlook a vessel in the lock at the upper level. His position at the controlling levers is so situated that he has a clear view of the full space of each gate, when approaching miter, and can witness and manipulate the complete and careful mitering.

(*c*) The electrical equipment for lighting is one to which much study might be given. In the case at hand, that method which was most simple and at once most economical was adopted. This is a constant potential system, using the Magnetite arc lamp in circuits of six in series, across the 550 volt circuit. This lamp was adopted owing to its high efficiency and illuminating power and the long life of its electrodes or 'carbons.' Of the renewable one, it has a life of from 140 to 160 hours, while the permanent one has a life of upwards of 2,000 hours. By this we may see that 'trimming' would be necessary but twice a month as regards the renewable carbon, while the permanent carbon should be good for a season of navigation. This, it will be noticed, is an important item in maintenance. These lamps require four amperes at 80 volts, or, approximately, ·43 H.P. at the lamp, or, say, ½ H.P. at the switch-board. When arranged in series of six lamps, they require 480 volts per circuit, which on a 550 volt line, gives an ample allowance for drop or line-loss.

The lighting outside the limits of the lock is accomplished by suspending the lamps from cross-arms on wooden poles, set in the cribs or canal bank at approximately 400 feet apart. This spacing of lamps was arrived at by the determination of the direction of greatest field of illumination from inclosed arc lamps, and by the same process, the height of 30 feet was found to give the greatest distribution of light. At this height the wires are to be run and supported by poles at 100 feet spacing, owing to the lesser opportunity for grounding upon small trees, &c., and also to give greater support to the wires when loaded with sleet, snow, &c.

Provision may be made for protecting the line against theft during periods when not in use by the introduction of relay and circuit detectors, in such manner that any tampering with the wires will result in an immediate alarm being given to the nearest watchman's quarters.

The estimates for this item embrace the necessary number of lamps, poles, cross-arms, braces, insulators, lightning arresters and wires for feeder circuits.

(*d*) The matter of unwatering or bailing the lock was gone into, with the result that an equipment of two units of electrically driven centrifugal pumps were estimated for. Two units were provided in order to obviate, as far as possible, the results of a break-down of pumping machinery, thereby preventing unwatering.

Centrifugal pumps were adopted in preference to reciprocating pumps on account of their higher efficiency. This item embraces the necessary switch connections, starting box, motor and pump set, and all wires and regulating devices necessary.

(*e*) The machinery was estimated from the weights of parts based upon an assumed price per pound for each class of material. The machines were designed by the writer and an endeavour was made to combine simplicity, strength and compactness. It was assumed that these machines would be placed behind the lock walls beneath the coping for the operation of the gates and valves of single locks and, in the case of valves for the flights, the operating machinery is let into the recess beneath the coping over the valve wall.

In this single instance referred to (*a*) page 443, in which hydraulic turbines were not used, i.e., at North Bay, in the line from Trout lake to Lake Nipissing, called Trout Lake lock, a suction gas producer and gas engine plant were estimated to drive the electrical generators. This plant was designed with a capacity to operate the lock, operate one drawbridge and light three miles of canal, and is consequently somewhat more expensive of installation.

This suction gas producer plant was adopted in preference to a steam driven plant on account of the following advantages:

No smoke,

No chimney,

Less space required and less housing,

Less labour required,

No skilled labour required,

No danger from explosions,

Greater economy of fuel.

Of the latter, tests have shown that with the best equipped simple expansion steam engine, the expenditure for fuel is eight pounds of bituminous coal per brake H. P. hour while the suction gas producer shows one pound of anthracite coal per brake H. P. per hour. In point of cost this represents a ratio (using bituminous coal at $3 per ton or anthracite coal at $7 per ton) of 35 to 120.

On a basis of 75 H. P. hours of power required for gates and valves at a single lock of 36 lockages, 25 H. P. hours of power required to make 72 operations of the drawbridge and 250 H. P. hours of power required for 40 arc lamps burning 12 hours, and 50 H. P. hours for losses between the engines and the lamps and motors, there would be required 400 H. P. hours per day. This amount produced at the rate of eight pounds of bituminous coal per brake H. P. hour would be 3,200 pounds per day or 342·4 tons in 214 days as a season of navigation. At $3 per ton, this would cost $1,027 per season. The same amount of power, i.e., 400 H.P. hours, at the rate of one pound of anthracite coal per brake H. P. hour, would be 400 pounds per day or 44·8 tons in 214 days. At $7 per ton, this would amount to $314, showing a saving per annum for fuel of $714.

All operating plants were so designed as to be duplex in every feature, and so arranged as to allow of four combinations for operation in case of a break-down of one of their parts.

Following is a summary of the estimates:—

Factor.	Single locks.	Flights.
Power plant	$ 7,500	$ 7,500
Electric power equipment	5,000	9,000
Electric light equipment	2,000	2,500
Bailing outfit	2,000	2,000
Machinery and valves	11,000	25,000
	$27,500	$46,000

It will be noted here that the above includes not only the appliances for the generation of power, for the manipulation of gates and valves, for lighting the locks and their guide cribs, and from 1,000 to 3,000 feet of land-line at each, for bailing or unwatering the lock, for two buildings or operating cabins at each single lock or three at each flight of two locks, but also for the gate arms, valve rods, valves and their individual machinery, which were estimated for by the district staff.

Excluding, for purposes of comparison, the items of electrical interlocking, electric lighting and bailing, our estimate becomes:—

Factor.	Single locks.	Flights.
Power plant	$ 7,500	$ 7,500
Operating equipment	4,000	8,000
Machinery, &c	11,000	25,000
	$22,500	$30,500

To arrive at an estimate of the cost of electrical equipment for the locks of the Montreal district, and owing to the fact that electrical equipment was not decided upon until the work had been practically completed for the Nipissing district, the writer was called upon by Mr. Coutlee, the district engineer of the Montreal and Ottawa district, for an approximate estimate, based upon the findings in the study of locks in the Nipissing district; the results in the foregoing summary may apply safely for locks between Montreal and the Des Joachims rapids of the Ottawa river.

No designs were made for operating machines for the type of filling valves to be used on the locks of the Montreal district nor for their pumping outfits, consequently these should be balanced with the similar parts estimated for use with the locks of the Nipissing district in order to arrive at the totals to be used for the complete estimate for the locks in that district.

Accompanying this report are the following drawings:—

A tracing of the outline of coping of a flight of locks, showing the general scheme of interlocking circuits.

A tracing of the outline of coping of a single lock, showing the general scheme of interlocking circuits.

A tracing showing sketch of diagram of circuits from generators to motors and lamps.

A tracing showing sketch of assembly of switch board at lock.

A tracing showing sketch of diagram of connections for switch board at lock.

A tracing showing sketch of assembly of controllers for one operating cabin.

A detail drawing of machine for operating each gate arm.

A detail drawing of machine for operating 'butterfly' valves with lifting stem.

A detail drawing of machine for operating control valves of 'Cluett' automatic valve.

A detail sketch of alternative design of machine for operating gate arm.

A detail sketch of alternative design of machine for operating 'Cluett' automatic valve.

A pencil sketch on detail paper of lay-out of two-unit suction gas producer and engine plant.

Referring to the sketch of the diagram of circuits, the generators as shown may be used singly or in parallel and, for this purpose, a separate panel is set up in the switch board at the power plant for each generator with balancing buss-bar running across the back of both panels (not shown in the design). Each generator panel is equipped with ammeter, volt meter, rheostat and main switch. From the generator panels the power circuits are led to the feeder panels.

The feeder panel is equipped with circuit breaker, feeder type ammeter, volt meter, main switch, lightning arrester and a recording watt-meter.

From the feeder panel the power circuit is conducted to the incoming line panel at one of the cabins at the lock. A full description of each panel of the switch boards at the lock cabins is given later.

From the incoming line panel the power circuit may be divided, one path going to the lighting panels from which the power is distributed into the lighting circuits. The other path leads to the storage battery panel.

From the storage battery panel the power for operating the gates and valves is led to the interlocking panel where it is controlled automatically by the interlocking arrangement of the circuits in connection with the interlocking circuit closing device.

From the interlocking panel the power circuit is led to the distributing panel, where it may be switched into any or all the circuits leading to the controllers governing the motors operating the gates and valves.

The operating cabin to which the power is conducted from the power plant contains all of the panels shown on the sketch of assembly of switch-board with as many lighting panels as may be necessary, and also the storage battery panel. The remaining cabin of a single lock, or two remaining cabins of a flight of two locks, contain only the interlocking panel, distributing panel and necessary lighting panel.

Referring to the sketch of assembly of switch-board, all instruments on all panels are designed to be back-connected. The panel 'A' is designed for incoming line panel. It is equipped with double pole carbon break circuit breaker with slate barrier between poles, ammeter, volt meter, volt meter switch (in order that the voltage of either circuit may be measured at any time), two double pole single-throw switches (one leading to the charging side of the storage battery switch and the other leading to the buss-bars of the lighting panels). The panel 'B' is designed for the storage battery panel. The power is received from the leads from switch on incoming line panel 'A' through a reverse current circuit breaker. This device prevents the battery from being discharged through the circuit leading back toward the power plant, by reason of grounds or slackening of speed or failing power of generator, as the slight reversal of current will cause the releasing mechanism to operate the reverse current circuit breaker thereby cutting out this circuit. From this circuit breaker the current passes to the double-pole double-throw switch terminals and through these to the battery connections. The battery cells are so arranged that when fully charged only that number required to give the normal voltage will be in series, but as the power is discharged, additional cells may be cut in by means of the end-cell regulator to give normal voltage. In charging the battery all the cells are put in series and with the power from the power plant at 550 volts, normal charge, we have a range of 50 volts for end-cell regulation. Switching in additional cells may be done by hand, but is best done by the automatic end-cell regulator which acts on the field coils of a small motor mounted on the back of the switch board having a shaft with an extension worm-screw and traveller carrying a contact finger which closes the circuit over the contact buttons of the end-cell switch.

In discharging the storage battery the double pole double-throw switch is set in the discharging position and the current then passes through an over-load circuit breaker on one leg of the circuit and an under-load circuit breaker on the other leg

of the circuit. The function of the over-load circuit breaker is, as its name signifies, to break the circuit, and thus protect the battery in case of accident, which would form a path for heavy discharge. The function of the under-load circuit breaker is to protect the battery in case of a failure on the part of the operator (if regulated by hand), to switch in additional cells when the voltage goes below the minimum allowable discharge rate, i.e., 1·8 volt per cell in the series; or if the automatic regulator should fail to work under similar conditions.

It may here be noted that, by the use of an additional switch, not shown on the sketch, and which may be located on the back of the panel, the power could be taken direct from the line or incoming line panel and passed to the interlocking panel, thereby doing away with the storage battery in case of accident. If this method was adopted a rheostat, or resistance box, should also be mounted on the panel to cut in sufficient resistance to bring the main line voltage of 550 down to that for which the several circuit breakers are wound, i.e., 500 volts.

On the storage battery panel is also shown two ammeters, a volt meter, a volt meter switch and a regulator switch. One ammeter is intended to float in the battery circuit showing the current in storage at all times, the other ammeter is to be of the feeder type and connected in the charging side of the governing switch, which shows the strength of current when charging. By means of the volt meter switch and the volt meter, the voltage in the circuit at any stage may be indicated, and by means of the regulator switch the regulator may be set for automatic (or hand) regulation, or may be cut out altogether.

Under ordinary circumstances, the regulator should be set for the full compliment of cells before throwing switch into the charging contacts. This operation may, at some later date, be arranged to take place automatically, but such a device, without the use of a 'booster,' has not been included in the plans here given.

From the storage battery panel, when discharging, the current goes to the interlocking panel 'D,' where it is controlled by a carbon-break circuit breaker of a peculiar type, in this case called a 'circuit closer.' This device is so arranged that by use of a shunt or auxiliary circuit carrying a small current and having to pass successively through several contact points at the other end of the lock, is made to actuate a plunger in a magnet coil, which plunger carries a pair of carbon break contact tongues. When all gates and valves are fully closed at one end of the lock, this shunt circuit has an uninterrupted path to the interlocking panel at the other end and causes the circuit-closer at that end to close, thereby completing the power circuit from the storage battery panel to the distributing panel. This interlocking panel is, in the case of a single lock, equipped with one of these circuit-closers, two pilot lamps and a double-pole single-throw switch. At the middle cabin of a flight of two locks the panel would be equipped with two circuit-closers, each controlled by a shunt circuit from the respective ends of the flight of locks.

The movement of the circuit-closer actuates a small switch which controls the pilot lamp in such manner that when open it shows a red light at 'P2,' while if closed, it shows a white light at 'P1.'

The distributing panel 'C' is equipped with two pair of buss-bars to which the power is conveyed from the interlocking panel. From the buss-bars the power is distributed by a number of double-pole single-throw switches equal to the number of motors to be controlled from that cabin. Each distributing panel has, in addition to the switches last named, a volt meter, a volt meter switch, one indicator lamp for each circuit and an ammeter. The ammeter is of the feeder type and shows the total current being used at all times. By means of the six-point volt meter switch, the voltage in any circuit may be indicated at any time. The indicator lamps show, when lighted, that the machine to which it is connected has completed its full travel and has closed the interlocking circuit governing the power circuit at the other end of the lock. Should one of these lamps remain unlighted when an operation of closing gates and valves has been made, it will show which factor is at fault or not fully closed.

The lighting panels 'E' (but one of which is shown on the sketch) are the controlling points for the lighting circuits. Under ordinary circumstances, as, for instance, where only the lock structure and its adjacent guide cribs are to be lighted, one panel at each end cabin would suffice; but if any great distance along the canal line is to be lighted, additional panels should be installed for the extra circuits required.

Each lighting panel should have an over-load circuit breaker with no voltage release so that the line may be protected against damage due to short circuit and also against injury due to interruption of potential from any other cause.

From the distributing panel of the switch-board, power is conducted to the controllers; a sketch of an assembly of six is shown on one of the drawings. These controllers are of the single-lever reversing type, and a cover of one is represented as removed, in order to show the switching contacts. A detailed description of this type of controller will not be given here, as they are a standard pattern, well known to the trade, and not requiring any special pattern for manufacturing.

From the controllers the power is conducted as previously described, to the motors at their respective machines, where, as shown on the sketches of operating machines, a governing switch mechanism is mounted, which completes the functions of interlocking and control.

Briefly, this is accomplished by placing on the standard of the machine a panel holding various switches and contacts. Motion is given, by means of gearing, to a worm screw carrying a traveller which trips a quick break, single pole, single throw switch, reversing the current at the instant the valve or gate is fully opened or fully closed. At the same moment a second switch is thrown into or out of contact which controls the indicating circuit to its corresponding lamp on the distributing panel. Another contact is made when the machine has completed its full closing travel (and which contact is broken immediately the machine is started in the opposite direction), which closes the interlocking circuit contacts controlling power at the opposite end of the lock.

Designs were not made for the machines to operate the large sluice gates suggested for use in the locks of the Montreal district, where side filling was to be introduced, owing to the fact that details of this method had not been fully decided upon. No study or comparison was made, owing to lack of time at my disposal, with any other systems of power transmission, as, for instance, installations at locks with direct constant potential of less than 500 volts or with an alternating current transmission and induction motors.

The writer believes that the subject should receive this study and a comparative estimate made of the cost of installation and operation, not only with direct constant potential at 500 volts but at other voltages with and without storage batteries, and with alternating current installation and the use of induction motors.

A more extended study of the subject of lighting with direct constant current system of transmission was made, but for the fact that there are few cases where long lines of distribution for the purposes of lighting are required, and that the small power plants may have two interchangeable units for lighting or power, or which may be coupled in parallel, it was decided to use direct constant potential system for the entire equipment and use direct current arc lamps in series.

Many of the little details of design about a lock equipment were, in this preliminary estimate, not gone into; such as heating and lighting the operating cabin, signalling by visual and audible means, setting and control of pumping outfits, capstans or winches for aid to vessels or use in heavy repairs, &c., &c.

Telephones should, of course, be a part of the equipment in order that the operators at either end of the lock and at the power plant, may at all times be in instantaneous communication with each other.

I shall be glad to supply any additional information in regard to the sketches accompanying this report, and to go into a study of comparative methods, &c., or to prepare complete working drawings upon which tenders may be received.

Thanking you for the uniform courtesy and untiring efforts on the part of yourself and the attachés of your office, to make my work with you pleasant and agreeable, I have the honour to be, sir,

Your obedient servant,

GEORGE F. CHISM,
Electrical Engineer.

NOTE.—Refer to plates 22, 22*a*, 22*b*, 22*c*, 22*d*, 22*e*.

APPENDIX E.

CONCRETE LOCK WALLS—DIMENSIONS, STABILITY, ETC.

Compiled by Arthur Surveyer, C.E.

The lock walls are of two different types supporting various pressures.

1. The chamber walls.

2. The upper and lower abutment walls.

The locks in all cases are built up on solid rock, and as the contract between the base of wall and the surface of rock is considered perfect, no film of water can penetrate underneath and consequently there will be no loss of weight by upward pressure.

CHAMBER WALLS.

As the natural rock forms the lower portion of the lock chamber, and the wall is built on top of it, we have only to consider the height from the rock surface to the coping of the wall. The minimum width of coping is 12′ as no great expense is incurred and a much increased mass is presented to the bumps of the boats.

The thrusts acting upon the wall are:—

1. The thrust tending to overturn the wall: there are 3 cases to be considered:—

(*a*) Chamber full, and no lock pressure from filling or from water in rear of wall.

(*b*) Chamber empty and pressure of filling in rear of wall.

(*c*) Chamber empty and pressure of water in rear of wall.

2. The thrust tending to slide the wall upon its base.

3. The crushing at the toe of wall in resisting overturning.

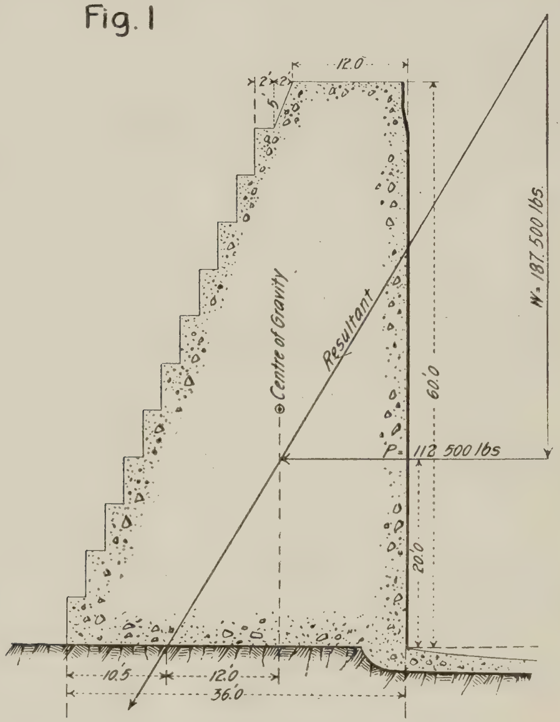
CALCULATIONS FOR LOCK CHAMBER WALLS.

1.—Stability Against Overturning.

(*a*) Chamber filled and no back pressure from filling or from water in the rear of wall. (*See* fig. 1.)

Concrete: = 125 lbs. per cubic foot.
Area of wall = 1,500 sq. feet.
Weight of wall = 1,500 × 125 lbs. = 187,500 lbs. = W
Water pressure = $60 \times 60/2 \times 62.5$ = 112,500 lbs. = P

Fig. I



Chamber Wall

$$\text{Factor of safety} = \frac{187{,}500 \times 22}{187{,}500 \times 20} = 1 \cdot 8$$

(b) Chamber empty and pressure of filling in rear of wall. (*See* fig. 2.)

Concrete = 125 lbs. per cubic foot.
Earth = 100 lbs. per cubic foot.
Area = 1,500 sq. feet.
Weight = 1,500 × 125 lbs. = 187,500 lbs. = W

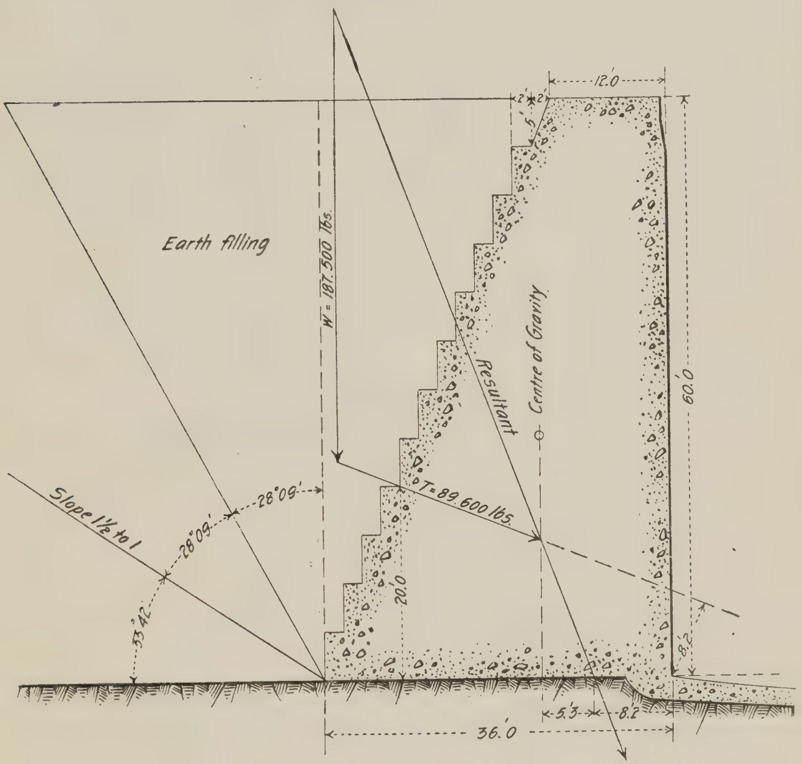
Area of triangle $\frac{56 \times 60}{2}$ 1,680 sq. feet.

Total weight of triangle = 168,000 lbs. = P

The pressure T of the earth, if the earth is assumed as level with the coping and without friction on the back of the wall, is

$$T = \frac{168{,}000 \times 32}{60} = 89{,}600 \text{ lbs.}$$

Fig. 2



Chamber Wall

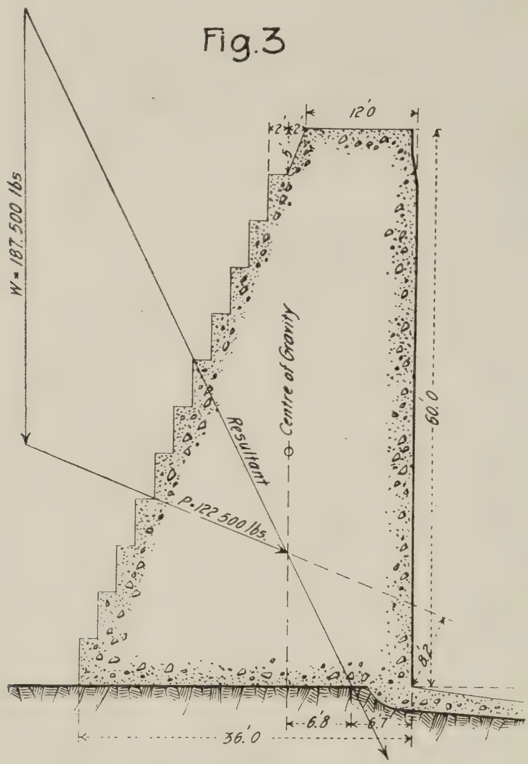
$$\text{Factor of safety} = \frac{187{,}500 \times 13.5}{89{,}600 \times 8.2} = 3.4$$

If we had taken into consideration the effect of the friction of the earth on back of wall, the factor of safety would have been much larger.

(*c*) Chamber empty and pressure of water in rear of wall. (*See* fig. 3.)

Area = 1,500 sq. feet.
Weight = 1,500 × 125 = 187,500 lbs. = W
Water pressure = 65 × 60/2 × 62.5 = 121,875 say 122,000 lbs. = P

Fig. 3



Chamber Wall

$$\text{Factor of safety} = \frac{187{,}500 \times 13.5}{122{,}000 \times 8{\cdot}2} = 2.5$$

It will be seen by the above diagrams that case (*a*), fig. 1, is the most dangerous so all walls have been calculated to resist with no backing, the water pressure from inside the chamber.

2.—Stability Against Sliding.

In order that the wall may not slide it is necessary that the product found by multiplying the co-efficient of friction by the sum of the weight of the wall and the vertical pressure of the water or of the earth shall be greater than the horizontal pressure of the water or of the filling.

Let us consider our most dangerous case (*see* fig. 1).

We have, if we adopt 0·7 as co-efficient of friction,

0·7 × 187,500 lbs. = 131,250 lbs. > water pressure = 112,500 lbs.

3.—Stability Against Crushing.

There is always a danger of the toe of the wall crumbling whilst resisting against the overturning moment.

This crushing strain can be calculated by the following formula:—

$$P = \frac{\text{Weight}}{\text{Base}} + \frac{6 \times \text{Weight} \times \text{centre of base to Resultant}}{\text{Base}^2}$$

If we apply this formula to the wall in fig. 3, we have

$$\text{Max. pressure at toe} = P = \frac{187{,}500}{36} + \frac{6 \times 187{,}500 \times 11.5}{36 \times 36} = 15{,}191 \text{ lbs.} = 7.6 \text{ tons per sq. foot.}$$

Trautwine gives from 12 to 18 tons per square foot as the crushing load of ordinary concrete one month old, so we are on the safe side.

ABUTMENT WALLS.

Hydrostatic Pressure transmitted by Lock Gates to Abutment Walls.

Area of gate = length of leaf × height = A B × H

$$\text{Mean hydrostatic pressure} = \frac{\text{height}}{2} \times 62.5 \text{ lbs.}$$

Total pressure on leaf = area of gate × mean pressure = Q

$$Q = H \times A\,B \times \frac{H}{2} \times 62.5 \text{ lbs.} \qquad (\textit{See fig. 4.})$$

This pressure is applied in the centre of the gate leaf and at one-third of the height above the recess floor.

The water pressure is transmitted to the hollow quoin by the heel post and can be thus calculated.

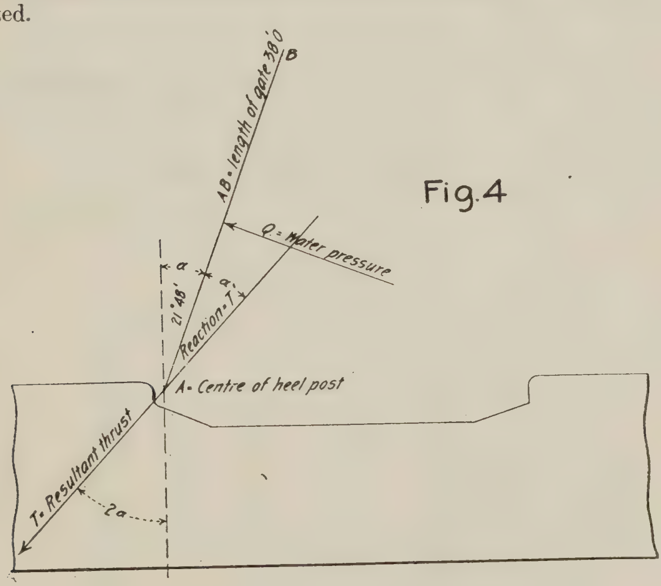


Fig. 4

Abutment Wall

Let us calculate the reaction T′ at the heel post:—

If we call a the angle of the gate with the normal to the face of the wall (in our case 21° 48′) and A B the total length of the gate leaf (in our case 38′) we have, by moments about B

$$Q \times \frac{AB}{2} = T' \times AB \sin \alpha$$

$$T' = \frac{Q}{2 \sin \alpha} = \text{Reaction}$$

$$T', \text{ reaction} = T, \text{ resultant thrust} = \frac{Q}{2 \sin \alpha}$$

It will thus be seen that the resultant thrust T from the water pressure Q on the gate will be applied at the centre of heel post at an angle 2α from the normal to the face of the wall.

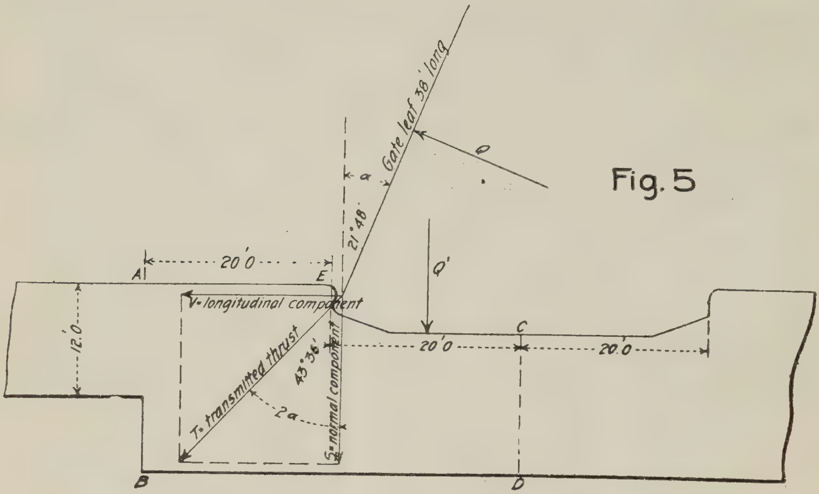


Fig. 5

Upper Abutment Wall

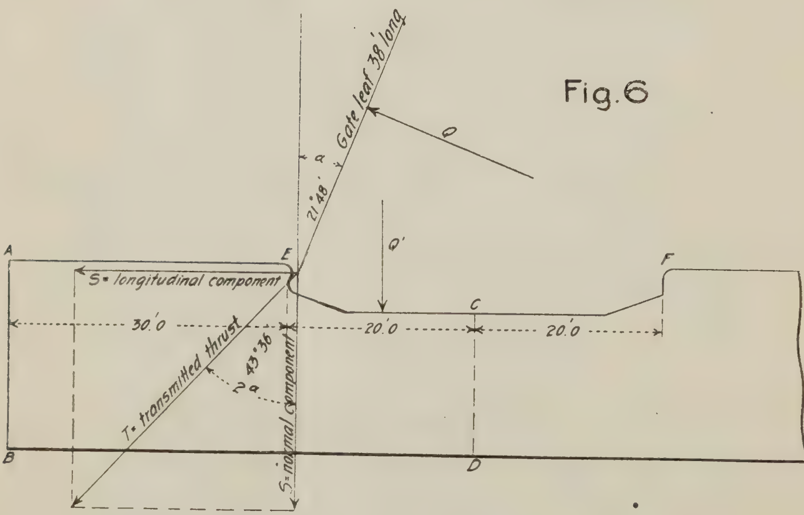


Fig. 6

Lower Abutment Wall

Maximum Pressures on Abutment Walls.

Let us consider a monolith of concrete A B C D (40′ long in the case of the upper abutment and 50′ long in the case of the lower abutment) and suppose that the lower pool is drawn out and the upper pool on the point of overflowing.

We have as before

$$Q = H \times A\,B \times \frac{H}{2} \times 62.5$$

$$T = \frac{Q}{2 \sin \alpha}$$

By decomposing T we obtain a longitudinal component V which acts parallel to the face of the wall and a normal component S tending to overturn the wall.

We have $S = T \cos 2\alpha$

But this block of concrete will also have to resist the effect of the water pressure on half the area of the gate recess.

$$Q' = H \times \frac{E\,F}{2} \times \frac{H}{2} \times 62.5$$

Thus the monolith A B C D will have to be calculated to resist the thrust of $S + Q' =$ total pressure $= P$.

It will be seen that in the upper abutment walls, the height of gate H is the same for all the locks whilst in the lower abutment walls H varies with each lock according to the difference of level between the lower and upper pools. So that the following discussion can be applied indifferently to the upper or lower abutment walls.

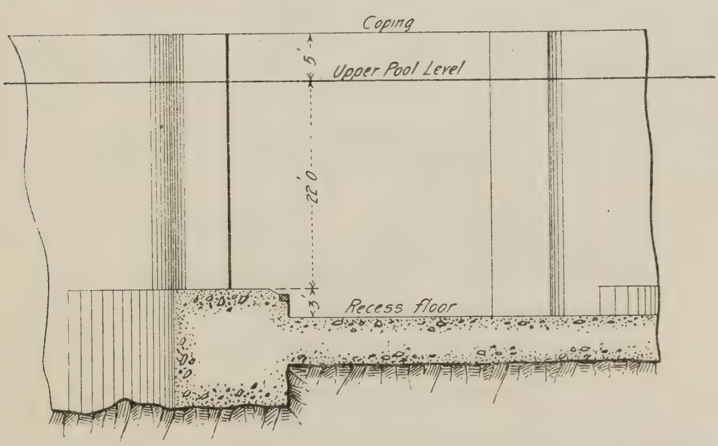
DIMENSIONS OF ABUTMENT WALLS.

As with the chamber walls the abutment walls rest on solid rock and we have three cases according to the elevation of rock.

(1.) The rock surface level with recess floor.
(2.) The rock surface below recess floor.
(3.) The rock surface above recess floor.

(1.) The rock surface level with the recess floor.
Let us calculate an upper abutment wall.

Fig. 7



Upper Abutment Wall

Pressure on wall transmitted from gate—

Area of gate $= 38\ (5 + 22 + 3) = 38 \times 30 = 1{,}140$ sq. feet.

Mean water pressure $= {}^{30}/_{2} \times 62.5 = 937.5$ lbs.

Total pressure on gate $= Q = 1{,}068{,}750$ lbs.

But we have $T = \dfrac{Q}{2 \sin \alpha}$ and $S = T \cos 2\alpha$

$$S = \frac{Q \cos 2\alpha}{2 \sin \alpha}$$

$$S = \frac{Q \times 0.724}{2 \times 0.371} = 1{,}068{,}750 \text{ lbs.} \times 0.975 = 1{,}042{,}031 \text{ lbs.}$$

Pressure on recess wall—

Area of gate recess $= 40 \times 30 = 1{,}200$ sq. feet.

Half area $= {}^{1200}/_{2} = 600$ sq. feet.

Mean water pressure $= {}^{30}/_{2} \times 62.5 = 937.5$ lbs.

Total pressure on half gate recess $Q' = 937.5 \times 600 = 562{,}500$ lbs.

Total pressure on block of concrete A B C D (*see* fig. 5) 40′ long, equals

$P = S + Q' = 1{,}042{,}031 + 562{,}500 = 1{,}604{,}531$ lbs.

The forces acting on the monolith considered are P the total pressure and W the weight of the concrete block.

We have taken 20′ as minimum width for the copings of both the upper and lower abutment walls.

Area of wall $= \left(30 \times 25 - \dfrac{5 \times 5}{2}\right) = (750 - 12.5) = 738$ sq. feet.

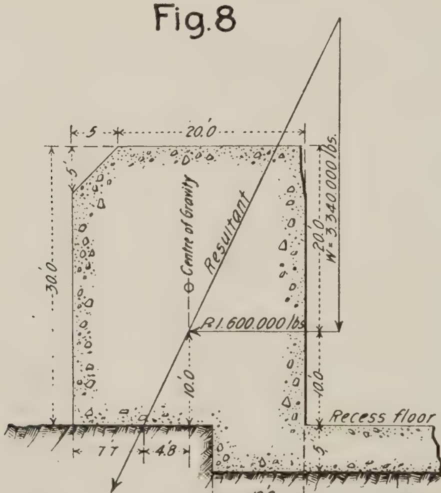
Total volume of concrete block $= (738 \times 40) -$ gate recess void

Gate recess void $= 2{,}820$ cubic feet.

Total volume of wall $= (29{,}520 - 2{,}820) = 26{,}700$ cubic feet.

Total weight of wall $= 26{,}700$ cubic ft. $\times 125$ lbs. $= W = 3{,}337{,}500$ lbs.

Fig. 8



Upper Abutment Wall
Section thro' gate recess

Factor of safety $= \dfrac{3{,}340{,}000 \times 12.5}{1{,}600{,}000 \times 10} = 2.6$

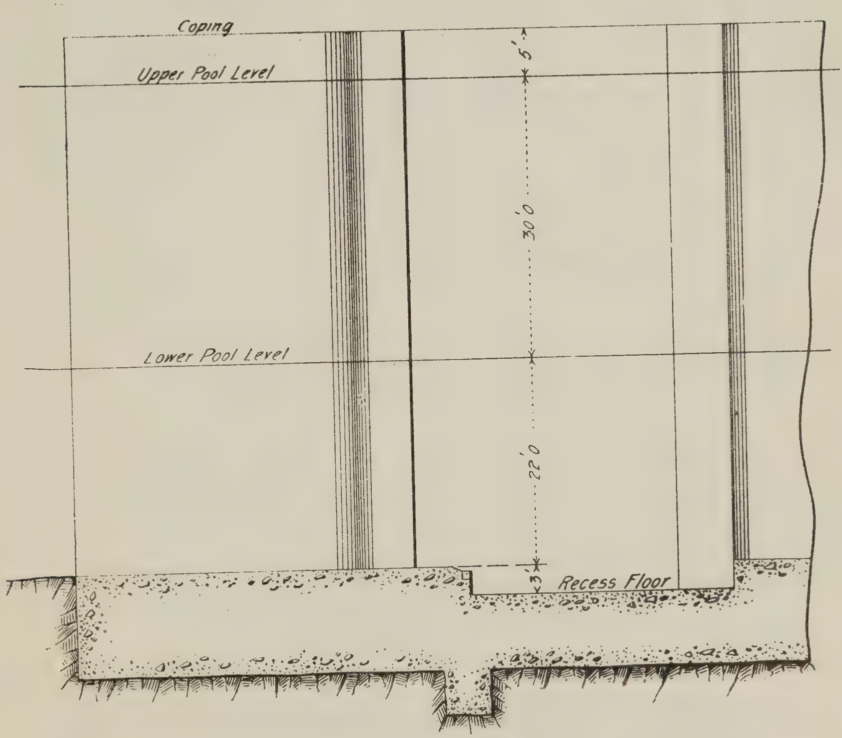
(2.) The rock surface below recess floor.

In this case we would build up to the recess floor level by filling in with stones between 2 walls and covering up with a solid concrete floor. These side walls would be calculated to withstand without any backing the pressure of the filling in the chamber and would have a minimum width equal to the base of the upper wall. We could then consider that we were building on rock and take as the upper wall the above calculated wall.

(3.) The rock surface above the recess floor.

Let us calculate a lower abutment wall, suppose that the difference of level between the lower and upper pools is 30′ and the height of rock above the floor recess is 30′.

Fig. 9



Lower Abutment Wall

Pressure on the gate—

The height of gate becomes $(3 + 22 + 30 + 5) = 60'$
Area of gate $= 38 \times 60 = 2{,}280$ sq. feet.
Mean water pressure $= {}^{60}\!/_{2} \times 62.5 = 1{,}875$ lbs.
Total pressure on gate $= Q = 1{,}875$ lbs. $\times 2{,}280 = 4{,}275{,}000$ lbs.

But we have $T = \dfrac{Q}{2 \sin a}$ and $S = T \cos 2a$

$$S = \frac{Q}{2} \frac{\cos 2a}{\sin a} \qquad a = 21° \, 48'$$

$$S = \frac{Q \times 0.724}{2 \times 0.371} = 4{,}275{,}000 \times 0.975 = 4{,}168{,}125 \text{ lbs.}$$

This pressure is applied 20′ above recess floor.

It will be seen that as the rock surface is 30′ above the recess floor, we will, after putting a concrete facing inside the chamber (10′ wide and 30′), have to calculate a wall 30′ high. This wall will have to stand the full hydrostatic pressure Q′ applied 10′ above its base and at the same point a proportion S′ of the pressure S transmitted from the gate by the heel post. S is applied 20′ above recess floor, and if we suppose that the post acts as a girder the pressure at the coping will be $\frac{S}{3}$ and at the recess floor $\frac{2S}{3}$.

Given this we can calculate S′ the fraction of S applied 40′ above recess floor.

Taking the moments about the point of application of S we have

$$S' \times 20 = \frac{S}{3} \times 40$$

$$S' = \frac{2\ S}{3}$$

$$S' = \frac{2 \times 4{,}168{,}125}{3} = 2{,}778{,}750 \text{ lbs.}$$

Water pressure on gate recess wall—

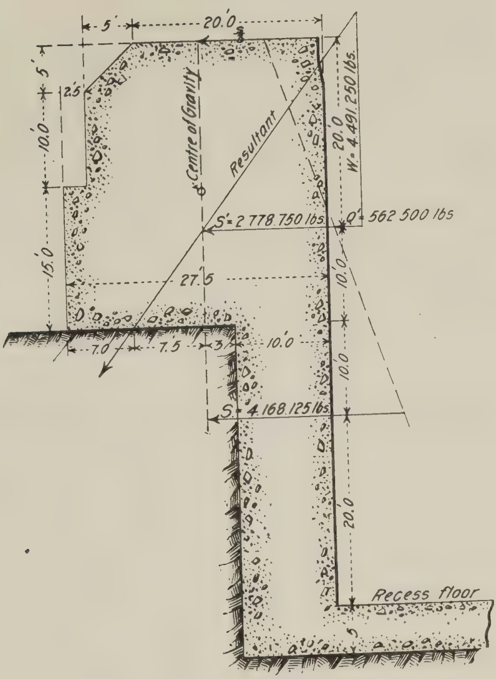
Half area of gate recess = 20 × 30 = 600 sq. feet.
Mean water pressure = $^{30}\!/_{2}$ × 62.5 = 937.5 lbs.
Water pressure Q′ = 937.5 × 600 = 562,500 lbs.
Then the total pressure P′ applied 40′ above recess floor will be
P′ = S′ + Q′ = 2,778,750 lbs. + 562,500 lbs. = 3,341,250 lbs.

The thrust P′ will be applied to the block of concrete A B C D (*see* fig. 6) 50′ long.

Area of wall $= \left(20 \times 30 + \frac{5 \times 5}{2} + 5 \times 25 + 2.5 \times 15 \right) = 775$ sq. ft. (*See* fig. 10)

Total volume of concrete block = (775 × 50) − gate recess void
Gate recess void = 2,820 cubic feet
Total volume of wall = (38,750 − 2,820) = 35,930 cubic feet
Total weight of wall = 35,930 cubic feet × 125 lbs. = 4,491,250 lbs.

Fig. 10



Lower Abutment Wall
Section thro' gate recess

$$\text{Factor of safety} = \frac{4{,}491{,}250 \times 14.5}{3{,}341{,}250 \times 10.0} = 1.9$$

APPENDIX

GEORGIAN BAY

ESTIMATE OF MATERIAL IN LOCK GATES,

Lock Dimensions:—Length, 650 feet;

Compiled by A. J. MATHESON,

$$W=[(\cdot000533\,D+\cdot0276\quad b^2+(-\cdot064\,D-1\cdot876)\quad b+1\cdot93\,D+51\cdot75]\quad H^2+[(\cdot06$$
$$b^2+(-315\cdot89\,D+5658\cdot6)$$

W=Weight in lbs. of steel in one leaf of single skin mitering gate;

	Location.	Number of Gates.		Elevation of Sill above M.S.L.	Least depth on Sill below Gate, in feet.	Height of Gate.	Extreme Head, in feet.	Weight of Gate Complete (Two Leaves). Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.
1	Montreal	2	Lower	— 4	22	60	38	530390	17900	900	5200	2600
		2	Upper	+30	0	26	26	215600	15800	700	5200	2200
2	Verdun	2	Lower	30	22	44	22	347950	15800	700	5200	2200
		2	Upper	44	0	30	30	251480	15800	700	5200	2200
3	Ste. Anne	2	Lower	44	22	34	12	258320	15800	700	5200	2200
		2	Upper	53	0	26	26	215600	15800	700	5200	2200
4	Pointe Fortune	2	Lower	53	22	66	44	611180	17900	900	5200	2600
		2	Upper	93	0	26	26	215600	15800	700	5200	2200
5	Hawkesbury	2	Lower	93	22	51	29	421860	15800	700	5200	2200
		2	Upper	113	0	31	31	260920	15800	700	5200	2200
6	Hull No. 1	2	Lower	118	22	54	32	456340	15800	700	5200	2200
		2	Upper	146	0	26	26	215600	15800	700	5200	2200
7	Hull No. 2	2	Lower	146	22	53	31	444660	15800	700	5200	2200
		2	Upper	173	0	26	26	215600	15800	700	5200	2200
8	Chats	2	Lower	173	22	76	54	760850	17900	900	5200	2600
		2	Upper	223	0	26	26	215600	15800	700	5200	2200
9	Chenaux	2	Lower	223	22	61	39	543380	17900	900	5200	2600
		2	Upper	258	0	26	26	215600	15800	700	5200	2200
10	Rocher Fendu No. 1	2	Lower	258	22	61	39	543380	17900	900	5200	2600
		2	Upper	293	0	26	26	215600	15800	700	5200	2200
11	Rocher Fendu No. 2	2	Lower	293	22	61	39	543380	17900	900	5200	2600
		2	Upper	328	0	26	26	215600	15800	700	5200	2200
12	Paquette	2	Lower	328	22	46	24	368120	15800	700	5200	2200
		2	Upper	348	0	26	26	215600	15800	700	5200	2200
13	Des Joachims	2	Lower	348	22	66	44	611180	17900	900	5200	2600
		2	Upper	388	0	26	26	215600	15800	700	5200	2200
14	*Rocher Capitaine	1	Lower guard	388	0	26	26	215600	15800	700	5200	2200
		2	Lower	388	22	56	34	480280	15800	700	5200	2200
15		2	Intermediate	418	0	56	56	557160	17900	900	5200	2600
		2	Upper	448	0	26	26	215600	15800	700	5200	2200
16	Deux Rivières	1	Lower guard	448	0	26	26	215600	15800	700	5200	2200
		2	Lower	448	22	56	34	480280	15800	700	5200	2200
		2	Upper	478	0	26	26	215600	15800	700	5200	2200
17	Mattawa	1	Lower guard	478	0	26	26	215600	15800	700	5200	2200
		2	Lower	478	22	36	14	274740	15800	700	5200	2200
		2	Upper	488	0	26	26	215600	15800	700	5200	2200
18	Plain Chant	1	Lower guard	488	0	26	26	215600	15800	700	5200	2200
		2	Lower	488	22	56	34	480280	15800	700	5200	2200
		2	Upper	518	0	26	26	215600	15800	700	5200	2200
19	Les Epines	1	Lower guard	518	0	26	26	215600	15800	700	5200	2200
		2	Lower	518	22	43	21	338140	15800	700	5200	2200
		2	Upper	535	0	26	26	215600	15800	700	5200	2200

F.

SHIP CANAL SURVEY.

DERIVED FROM GOLDMARK'S FORMULAE.

Width, 65 feet; Depth on sill, 22 feet.

Can. Soc. C. E.—November 9, 1907.

$D+\cdot 557)\ b^2+(10\cdot 022\ D-97\cdot 16)\ b-352\cdot 44\ D+5848\cdot 3]\ H+[(2\cdot 296\ D-33\cdot 215)\ b+13577\ D-200\cdot 100]$

b=breadth of Lock in feet; D=Depth on sill; H=Extreme head in feet.

Total for Two Sets of Gates.					Total for Lock.						Remarks.
Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.	Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.	Total Weight, in lbs.	Regulated Water Surface.
1060780	35800	1800	10400	5200	1491980	674000	3200	20800	9600	1592980	18 to 35.
431200	31600	1400	10400	4400							52
695900	31600	1400	10400	4400	1198860	63200	2800	20800	8800	1294460	
502960	31600	1400	10400	4400							67 to 74
516640	31600	1400	10400	4400	947840	63200	2800	20800	8800	1043440	
431200	31600	1400	10400	4400							75
1222360	35800	1800	10400	5200	1653560	67400	3200	20800	9600	1754560	
431200	31600	1400	10400	4400							115
843720	31600	1400	10400	4400	1365560	63200	2800	20800	8800	1461160	
521840	31600	1400	10400	4400							135
912680	31600	1400	10400	4400	1343880	63200	2800	20800	8800	1439480	
431200	31600	1400	10400	4400							168
889320	31600	1400	10400	4400	1320520	63200	2800	20800	8800	1416120	
431200	31600	1400	10400	4400							195
1521700	35800	1800	10400	5200	1952900	67400	3200	20800	9600	2053900	
431200	31600	1400	10400	4400							245
1086760	35800	1800	10400	5200	1517960	67400	3200	20800	9600	1618960	
431200	31600	1400	10400	4400							280
1086760	35800	1800	10400	5200	1517960	67400	3200	20800	9600	1618960	
431200	31600	1400	10400	4400							315
1086760	35800	1800	10400	5200	1517960	67400	3200	20800	9600	1618960	
431200	31600	1400	10400	4400							350
736240	31600	1400	10400	4400	1167440	63200	2800	20800	8800	1263040	
431200	31600	1400	10400	4400							370
1222360	35800	1800	10400	5200	1653560	67400	3200	20800	9600	1754560	
431200	31600	1400	10400	4400							410
960560	31600	1400	10400	4400	2721680	114800	5300	36400	16200	2894380	
1143320	35800	1800	10400	5200							440
431200	31600	1400	10400	4400							470
960560	31600	1400	10400	4400	1607360	79000	3500	26000	11000	1726860	
431200	31600	1400	10400	4400							500
549480	31600	1400	10400	4400	1196280	79000	3500	26000	11000	1315780	
431200	31600	1400	10400	4400							510
960560	31600	1400	10400	4400	1607360	79000	3500	26000	11000	1726860	
431200	31600	1400	10400	4400							540
676280	31600	1400	10400	4400	1323080	79000	3500	26000	11000	1442580	
431200	31600	1400	10400	4400							

APPENDIX

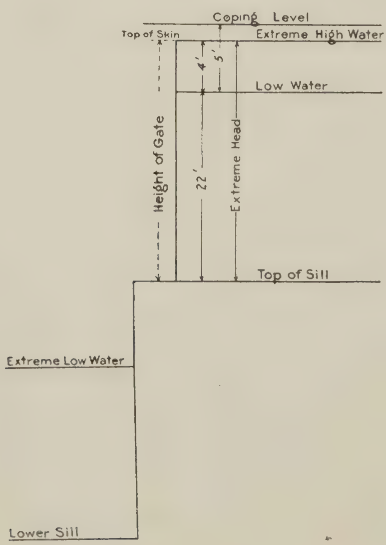
Location.	Number of Gates.	Elevation of Sill above M.S.L.	Least depth on Sill below Gate, in feet.	Height of Gate.	Extreme Head, in feet.	Weight of Gate Complete (Two Leaves). Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.
20 *Lower Paresseux	1 Lower guard	535	0	26	26	215600	15800	700	5200	2200
	2 Lower	535	22	56	34	480280	15800	700	5200	2200
	2 Intermediate	565	0	56	56	557160	17900	900	5200	2600
21	2 Upper	595	0	26	26	215600	15800	700	5200	2200
22 *Upper Paresseux	1 Lower guard	595	0	26	26	215600	15800	700	5200	2200
	2 Lower	595	22	56	34	480280	15800	700	5200	2200
	2 Intermediate	621	0	60	60	615320	17900	900	5200	2600
23	2 Upper	651	0	30	30	251480	15800	700	5200	2200
24 North Bay	2 Upper	651	0	30	30	251480	15800	700	5200	2200
	2 Lower	626	22	55	33	468220	15800	700	5200	2200
	1 Lower guard	626	0	26	26	215600	15800	700	5200	2200
25 Chaudière	2 Upper	626	0	26	26	215600	15800	700	5200	2200
	2 Lower	602	22	50	28	410740	15800	700	5200	2200
	1 Lower guard	602	0	26	26	215600	15800	700	5200	2200
26 Five Mile Rapids	2 Upper	602	0	26	26	215600	15800	700	5200	2200
	2 Lower	578	22	50	28	410740	15800	700	5200	2200
	1 Lower guard	578	0	26	26	215600	15800	700	5200	2200
27 Dalles	2 Upper	578	0	26	26	215600	15800	700	5200	2200
	2 Lower	556	22	48	26	289060	15800	700	5200	2200
	1 Lower guard	556	0	26	26	215600	15800	700	5200	2200

RIVIERE DES

Location.	Number of Gates.	Elevation of Sill above M.S.L.	Least depth on Sill below Gate, in feet.	Height of Gate.	Extreme Head, in feet.	Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.
1A Rivière des Prairies	2 Lower	— 6	22	50	28	410740	15800	700	5200	2600
	2 Upper	+18	0	26	26	215600	15800	700	5200	2200
2A Recollet	2 Lower	18	22	61	39	543380	17900	900	5200	2600
	2 Upper	53	0	26	26	215600	15800	700	5200	2200

* Two locks in flight.

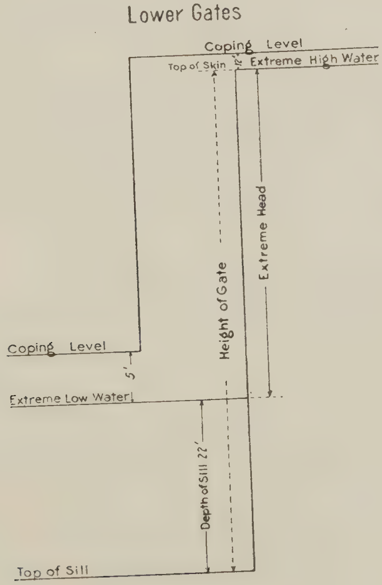
Intermediate and Upper Gates



F—*Continued.*

Total for Two Sets of Gates.					Total for Lock.						Remarks.
Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.	Gate Steel, in lbs.	Steel Castings, in lbs.	Bronze Bushings, in lbs.	Anchor Bars and Beams, in lbs.	Steel Pins and Wedges, in lbs.	Total Weight, in lbs.	Regulated Water Surface.
....	....	....	....	....	....	....	....	....	....	....	557
960560	31600	1400	10400	4400	2721680	114800	5300	36400	16200	2894380	
1114320	35800	1800	10400	5200	....	....	....	....	....	....	587
431200	31600	1400	10400	4400	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	617
960560	31600	1400	10400	4400	2909760	114800	5300	36400	16200	3082460	
1230640	35800	1800	10400	5200	....	....	....	....	....	....	647
502960	31600	1400	10400	4400	....	....	....	....	....	....	
502960	31600	1400	10400	4400	1655000	79000	3500	26000	11000	1774500	673 to 677
936440	31600	1400	10400	4400	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	
431200	31600	1400	10400	4400	1468280	79000	3500	26000	11000	1587780	648
821480	31600	1400	10400	4400	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	
431200	31600	1400	10400	4400	1468280	79000	3500	26000	11000	1587780	624
821480	31600	1400	10400	4400	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	
431200	31600	1400	10400	4400	1424920	79000	3500	26000	11000	1544420	600
778120	31600	1400	10400	4400	....	....	....	....	....	....	
....	....	....	....	....	....	....	....	....	....	....	578 to 584.7
36382060	1653600	75400	530400	232400	38753660	1827400	83100	587600	256600	41508360	
PRAIRIES ROUTE.											
821480	31600	1400	10400	5200	1252680	63200	2800	20800	9600	1349080	16 to 35
431200	31600	1400	10400	4400	....	....	....	....	....	....	
1086760	35800	1800	10400	5200	1517960	67400	3200	20800	9600	1618960	40
431200	31600	1400	10400	4400	....	....	....	....	....	....	
2770640	130600	6000	41600	19200	2770640	130600	6000	41600	19200	2968040	75
35514020	1590400	72600	509600	224400	37885620	1764200	80300	566800	248600	40545520	

Lower Gates



APPENDIX G.

STONEY SLUICE GATES.

Office of HENRY GOLDMARK, Consulting Engineer,
216 Board of Trade Building,
MONTREAL, January 7, 1907.

A. ST. LAURENT, Esq.,
Asst. Chief Engineer, Dept. of Public Works,
Georgian Bay Ship Canal Survey,
Ottawa, Ont.

DEAR SIR,—As requested by you, I have investigated the question of Stoney sluice gates for the proposed Georgian Bay Ship Canal and beg to send you herewith a blue print giving general plans of such gates as I should recommend, as well as of the masonry piers required, and a sketch of the machinery for operating the gates.

I also enclose an estimate of the weight of the steel work, cast-iron and machinery, as well as the quantity of masonry in the piers.

All of the above is in accordance with the memorandum sent me for guidance and covers, I believe, all necessary points.

The estimates and plans are based on detailed designs for a number of gates of different widths, which were computed, in order to determine the most economical span, that is, the span which would cost the least per lineal foot of opening, taking into account the cost not only of the metal work but also of the masonry.

The appended estimates give the results for gates 25 feet and 30 feet deep and for clear openings of 30, 40 and 50 feet.

The total cost for one span, including both the metal work and one pier, is given, and also, for purpose of comparison, the cost per lineal foot for the different widths of opening.

As shown in the tables, the total cost per lineal foot does not vary greatly for different spans, although the 40-foot opening is slightly the cheapest. Additional estimates, not given here, have shown that spans less than 30 feet and over 50 feet are less economical than those that lie between these limits.

Hence, a 40-foot span was taken in making the plans, this length being convenient in transportation and erection, without increasing unduly the total number of gates to be operated.

The unit prices adopted were the following:—

Structural steel, erected in place..........	$0 05½	per lb.
Cast-iron "	0 03	"
Operating machinery "	0 09	"
Concrete "	8 00	per cub. yd.

The plan submitted shows the construction clearly with all the principal dimensions and cross-sections of the girders. The horizontal girders are spaced so as to bring an equal amount of water pressure on each girder, making all the girders, except the top and bottom ones, exactly alike.

There is one skin plate only, so that all parts are accessible for inspection and painting. The rollers are 8 inches in diameter closely spaced except near the top.

The horizontal girders are designed to withstand the following loading:—

At the bottom the full hydrostatic head.

At the top a load of 625 lbs. per square foot of gate surface, equivalent to a head of 10 feet.

At intermediate points, a load increasing uniformly from the load at the top to the maximum at the bottom.

The excess loading above that due to the hydrostatic head is assumed in order to provide for accidental blows to the gate, pressure from ice, and also in order to take care of the increased loading near the top, which the vertical stiffeners of the gate are certain to produce.

Under these loadings, the maximum unit stresses in the structural steel are the following:—

Tension	1200 lbs. per sq. inch on the net section.	
Compression	10000 " " "	gross "
Shear..	10000 " "	

The minimum thickness of metal in the primary members was taken at ½-inch and in the secondary members at ⅜-inch.

The piers were calculated to withstand the horizontal pressure transmitted to them by the gates, in addition to the direct water and ice pressures.

An upward water pressure on the bottom of the masonry was also assumed. This pressure in pounds per square foot was taken as equivalent to thirty times the head in feet, that is, for the gates 25 feet deep, this pressure was 750 pounds per square foot, and for the 30-foot gates, 900 pounds per square foot, this being very nearly one-half the full hydrostatic head.

The piers were designed against overturning and sliding. The resultant line of pressure is nowhere outside the middle, and the pressures on the edges are very moderate. The tangent of the angle which the resultant line of pressure makes with the horizontal is never in excess of 0·5, giving ample safety against sliding.

In making the above calculations, the weight of the entire pier was taken into account. It was found that only a very small amount of reinforcing steel was required in order to bring the whole weight into action.

The weight of the gate leaf is fully counterweighted. There is a box girder as shown arranged to carry cast-iron counterweights of suitable sizes. This box is supported by steel cables. There are cast-iron chain links attached to the cable, which serve to produce equilibrium, as the gate is more or less immersed into the water.

The operating machinery is indicated on the plan. It consists of a simple train of gear wheels, by which the drum which carries the cable is operated by hand power. There is one apparatus at each end of the gate with a continuous shaft.

Very respectfully,

(Signed) HENRY GOLDMARK.

NOTE.—For type of "Stoney" sluice gates refer to plate 24.

ESTIMATE OF COST OF STONEY SLUICE GATES.

GATE FOR 30 FT. HEAD OF WATER.

Estimate for one Span (one Gate and one Pier).

Class.	Unit Prices.	30′ Span.		40′ Span.		50′ Span.	
		Amount.	Cost.	Amount.	Cost.	Amount.	Cost.
	$ cts.		$ cts.		$ cts.		$ cts.
Steel.............. Lbs.	0.05½	146,040	8,032 20	202,160	11,118 80	272,000	14,960 00
Cast iron.......... "	0.03	87,540	2,626 20	125,800	3,774 00	168,550	5,056 50
Machinery.......... "	0.09	44,400	3,996 00	56,320	5,068 80	67,700	6,003 00
Concrete............C. yds.	8.00	1,050	8,400 00	1,306	10,448 00	1,562	12,496 00
Total..............	....	....	23,054 40	....	30,409 60	....	38,515 50

Estimate for one lineal ft. of Opening.

Steel.............. Lbs.	0.05½	4,868	267 74	5,054	277,97	5,440	299 25
Cast iron.......... "	0.03	2,918	87 54	3,145	94 35	3,371	101 13
Machinery.......... "	0.09	1,480	133 20	1,408	126 72	1,334	120 06
Concrete............C. yds.	8.00	35	280 00	32·65	261 20	31·24	249 92
Total..............	....	....	768 48	....	760 24	....	770 31

GATE FOR 25 FT. HEAD OF WATER.

Estimate for one lineal foot of Opening (Metal Work and Masonry).

Medium steel........ Lbs.	0.05½	3,626	199 43	3,748	206 14	3,872	212 96
Cast iron.......... "	0.03	2,123	63 69	2,280	68 40	2,852	73 56
Machinery.......... "	0.09	1,254	112 86	1,188	106 92	1,123	101 07
Concrete............C. yds.	8.00	21·5	172 00	20·15	161 20	19·36	154 88
Total..............	....	....	547 98	....	542 66	....	542 47

Estimate for one Span (one Gate and one Pier).

Steel.............. Lbs.	0.5½	108,780	5,982 90	149,920	8,245 60	193,600	10,648 00
Cast iron.......... "	0.03	63,690	1,910 70	91,220	2,736 00	122,600	3,678 00
Machinery.......... "	0.09	37,620	3,385 80	47,520	4,276 80	56,150	5,053 50
Concrete............C. yds.	8.00	645	5,160 00	806	6,448 00	968	7,744 00
Total..............	....	....	16,439 40	....	21,706 40	....	27,123 50

APPENDIX H.

ESTIMATE OF HYDRAULIC MACHINERY FOR OPERATING LOCK GATES AND VALVES.

Prepared by Mr. R. L. Haycock, Mechanical Engineer.

This estimate includes:—

- Turbines and governing valves.
- Shafting—gearing—pulleys and belts.
- High pressure duplex pumps.
- Accumulators.
- Piping.
- Lock gate engines.
- Valve engines.

This estimate does not include buildings, foundations or sluice-ways.

Attached diagram gives arrangement of parts.

Pumping plant—		
Two turbines 36-inch and valves		$4,000 00
Shafting, gears, &c.		2,000 00
Two high pressure duplex pumps, &c., piping		6,000 00
Three accumulators and piping		14,000 00
Total cost of pumping plant		$26,000 00
Valve and gate engines—		
Eight lock gate engines, pipes and valves	$23,500 00	
Four valve engines, pipes and valves	9,000 00	
Pipe mains	2,500 00	
Total cost of gate and valve equipment		$35,000 00
Engineering and incidentals		4,000 00
Total cost for one lock complete		$65,000 00

The above equipment of pumping plant would also be sufficient to supply power for two or three locks in a group.

DESCRIPTION OF PLANT.

Water from the upper level is brought to the pumping plant by taking it from the valve flume or by separate flume from the dam. It passes through the turbines, which are governed by gates automatically operated by the accumulators, and is discharged to the lower level.

The turbines operate a horizontal shaft from which power is taken by belts to the duplex pumps. From the pumps the water passes to the accumulators and from there to the mains at 200 lbs. pressure.

Each turbine is capable of doing work alone, which allows one turbine as a spare.

Each pump is capable of doing the work alone, which gives one as a spare.

The shafting, clutches and pulleys are so arranged that either turbine can operate either pump.

The accumulators are of sufficient capacity for any two of them to supply the necessary head, thereby having one as a spare.

The accumulators are the piston weighted type. Cylinder vertical and fastened to the bare plate which is at floor level. Top of cylinder is about two feet above the floor. The piston carries the weights and travels up and down with the weights according to the amount of water used.

The pressure main extends from the accumulators along one side of the lock and the water is taken through branches to the Aiken valves and then to the engines to be operated.

The 'pressure main' and ' return main' are each 4 inch Dia. pressure main X heavy and return main standard pipe. All piping from the pressure main, to the cylinders to be operated, is 2 inch X heavy pipe.

Aiken valves have been selected on account of the extreme simplicity of operation and of mechanical construction. From experience they have been found to give the greatest satisfaction.

The only wearing parts are the cup leathers, which are removed and replaced by new when worn. It is necessary to remove only one bolt to take out spindles for repairs. These cup leathers should run a whole season without repairs on this work.

Aiken valves have been placed in operation in many of the largest steel plants after scrapping all other valves that had been doing the work and which gave continual trouble.

All gate and valve engines are operated from one side of the lock.

The gate engines are 18 inches Dia., 1¼ inches thick and have a stroke of 24 feet.

They exert a maximum perpendicular pull to the gate at instant of opening of 15 tons, and during the opening of the gate develop 23 H.P.

These engines contain cylinder, cross head and guides, connecting rod and bracket on gate.

The valve engines are 12 inch Dia. 1 inch thick and have a stroke of 6 feet.

They exert a pull of 10 tons to the bracket on the valves and during the opening of valves develop 4 H.P.

The engines on inlet side contain cylinder, cross head and guides, connecting rod, bell crank, connecting rod and bracket on valve.

The engines on inlet side contain cylinder, cross-head and guides, connecting rod, bell crank, connecting rod, cross-head and guides, connecting rod and bracket on valve.

All waste water is piped in a return main to a setting tank in the pumping plant from which the pumps draw their supply. This enables the use of a non-freezing mixture in colder weather without loss.

The glycerine non-freezing mixture in use is 20 per cent glycerine to 80 per cent water, and costs about 50 cents per gallon. It is hard on the packings of pumps, accumulators, engines and valves and gums slightly, and is no good as a lubricator. It is good for a few degrees below zero.

The oil used with entire satisfaction, is a by-product oil from the manufacture of parafine and should have a flash point of about 400 degrees Fahrenheit. This oil costs about 18 cents per gallon. It is like a thin cylinder oil and is a fair lubricant, will not destroy packings and in fact gives longer life to them than the water. This oil is good for 15 degrees below zero.

A complete equipment of one lock, as shown, would require 4000 imperial gallons.

If oil is used, cost would be $680.00 and the glycerine mixture would *cost $2,000.00* per lock.

To illustrate the operations necessary for working a boat through a lock we will take the case of a boat going from the upper to the lower level.

It will be necessary to have two men, the 'operator' and his 'assistant.'

First.—Operator goes to Aiken valves which govern the lower gates and closes these gates. His assistant watches the miter to insure a proper joint.

Second.—Operator goes to Aiken valves which govern the outlet valves and closes them, then opens the inlet valves and allows the lock to fill.

Third.—Operator goes to Aiken valves which govern the upper gates and opens them to allow the boat to enter.

Fourth.—When boat has been properly moored the operator closes these gates, his assitant watching miter to insure a proper joint.

Fifth.—Operator goes to Aiken valves which govern the inlet valves and closes them; then opens the outlet valves which allow the lock to empty.

Sixth.—Operator goes to Aiken valves which govern the lower gates and opens them to allow the boat to go out to the lower level.

It will be noticed the operator does all his work from one side of the lock, and, when he is operating the gates, he is close to them and knows exactly how they are acting.

I would suggest the employment of a mechanic for this position as he could take care of the power house during spare time. His assistant could be a handyman.

APPENDIX I.

ESTIMATE OF ACETYLENE LIGHTING SYSTEM FOR LOCK AND APPROACHES.

Prepared by R. L. Haycock, Mechanical Engineer.

This estimate includes:—

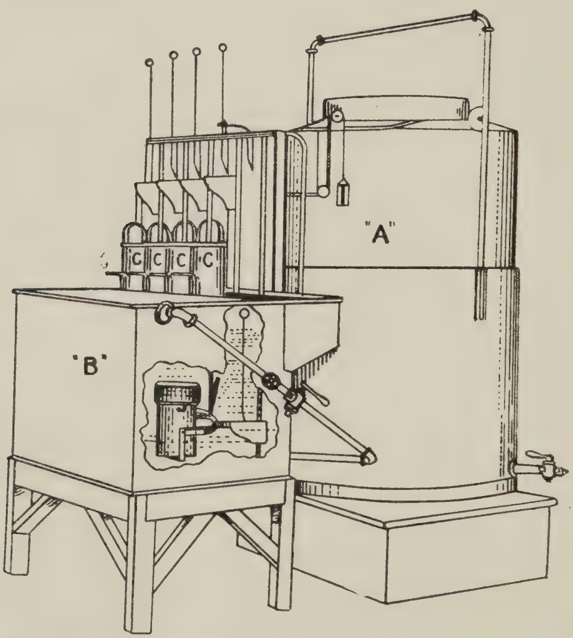
Generator.
Piping.
Lantern Posts.
Lanterns.

Attached diagram shows arrangement of parts:—

Generator complete	$	550.00
Piping		300.00
Posts		80.00
Lanterns		130.00
Total	$	1,060.00

DESCRIPTION OF SYSTEM.

The generator consists of a gasometer 'A' and a generator 'B.' The carbide being placed in movable cups 'C.'



These cups are fitted to a frame work and rest on a rack attached to the generator and tripped automatically as required by means of a tripping bar attached to the gasometer, the cups when tripped descending into the generator 'B' and turning up behind the partition as in the illustration.

The carbide being encased in the cup it is absolutely impossible for the water to attack it until it has passed behind the partition, when generation takes place.

The gas rises thoroughly washed and perfectly cool through the water behind the partition and thence into the gasometer 'A' which is of sufficient capacity to store the gas produced from one cup of carbide.

A duplicate set of cups is supplied and when one set has been submerged they can be easily withdrawn and dried, the duplicate set being charged and attached in their place.

The re-charging can be attended to at any time without interfering with the operation of the lights, and as there is no generator to open there is absolutely no danger in the process.

The points in favour of the machine are:—

No waste or over-generation.

Perfect safety.

No disagreeable odour.

Gas thoroughly washed and perfectly cool.

This generator would be capable of supplying one or more locks in a series and would be charged twice a month.

Generator could be placed near or in power house if hydraulic system is adopted.

The piping consists of $\frac{1}{4}$ inch and $\frac{1}{2}$ inch standard pipe for mains and $\frac{1}{2}$ inch X heavy to cross from one side of lock to the other. These cross pipes are taken from one side of the lock to the other and both ends of lock in case of breakage to one.

The posts are turned cedar about 15 feet long and stand 10 feet above the ground. Pipe goes up the centre of post.

Lanterns are similar to street gas lamps; burner consists of two $\frac{3}{4}$ ft. tips with capacity of about 100 candle power.

The advantages of this system of lighting are:—

- Low cost of plant.
- Ease of operation—automatic.
- Low cost of lanterns—in comparison to arc lamps.
- Low cost of piping—in comparison to electric wiring.
- Low expense of repairs. Only parts damaged are tips in lantern and these run whole season.
- No skilled labour.

APPENDIX J.

DERIVATION OF AMOUNT OF WATER REQUIRED FOR POWER AT SUMMIT LEVEL.

Report by Geo. F. Chism, M. Am. Soc. C.E.

The following calculations of the amount of power required at the two flights are based on the results of tests made on gates and valves of the Soulanges, Cornwall and Welland canals, with a suitable allowance for increased sizes and weights of the moving parts and increased areas, subject to wind pressures, etc.

The composite curve of the performance of the motors from the tests mentioned shows that for gates there is an inrush current at starting, which immediately falls to less than motor rating, coming up to about normal rating for a short period just previous to entering the gate recess or to making miter.

The following performances were therefore assumed for each gate and valve motor proposed for the locks of the Georgian Bay Ship canal.

20	h.p. for	5	seconds	= 100	h.p.	seconds.
10	"	10	"	= 100	"	"
5	"	30	"	= 150	"	"
3	"	60	"	= 180	"	"
5	"	10	"	= 50	"	"
10	"	5	"	= 50	"	"
		120		630		

Hence each pair of gate motors require 630 x 2 = 1260 h.p. seconds per movement. The assumptions for the operation of the valves are as follows:—

For opening:—

10	h. p. for	3	seconds	= 30	h. p. seconds.
7	"	3	"	= 21	"
5	"	10	"	= 50	"
2	"	44	"	= 88	"
		60		189	

Hence opening each pair of valves will require 189 × 2 = 380 h. p. seconds.

For closing:—

5	h. p. for	3	seconds	= 15	h. p. seconds.
1	"	57	"	= 57	"
		60		72	

Hence closing each pair of valves will require 72 × 2 = 144 or say 150 h. p. seconds.

Assuming that each lockage consists in returning the gates and valves to their original position, 36 lockages will require the following movements:—

A pair of gates	14 × 36 × 1,260	= 635,040	h. p. seconds.
" valves	4 × 36 × 380	= 54,720	"
" "	4 × 36 × 150	= 21,600	"
		711,360	

For the two flights this will be 2 × 711,360 = 1,422,720 h. p. seconds.

For illuminating both flights with 22 arc lamps per flight, and the stretch of land intervening with 16 arc lamps there will be required 60 arc lamps, which, at 480 watts per lamp at the lamp, will require 60 × ·643 = 38·58 h. p. (each lamp = ·643 at that wattage) and assuming that the long run will be twelve hours, there will be required 12 × 38·58 = 462·96, or say 463 h. p. hours, which reduced to h. p. seconds = 1,666,800 h. p. seconds.

The total power required per 24 hours for power and lighting then becomes:—

For power, 1,422,720 h. p. seconds.
For lights, 1,666,800 "

3,089,520

One h. p. second = 550 ft. lbs., and hence 3,089,520 h. p. seconds = 1,699,-225,000 ft. lbs. in 24 hours (rounded figure); reducing this to ft. lbs. per sec. we have 19,667 ft. lbs. per sec.

Taking water at 62·5 lbs. per cu. ft. and assuming a 60 ft. fall, we have each cu. ft. of water giving 3,750 ft. lbs. and 19,667 ÷ 3,750 = 5·24 cu. ft. per sec.

This is the theoretical amount of water required at the lamps and motors, and if we allow a very low efficiency for the various conversions at say 40 per cent there will be required 5·25 × 2·5 = 13·125 cu. ft. per sec. for a continuous run of 24 hours.

Of course if this run is restricted to a limited period of say 8 or 4 hours the continuous run will be correspondingly increased, at four hours, for instance, there would be required 78·75 cu. ft. per sec.

In your instructions given me at Ottawa you stated that 100 cu. ft. per sec. for 4 hours would be available and you will see by the foregoing statement that this amount has not been exceeded.

The very low factor of efficiency taken above added to the very high assumptions as to power required and the fact that we have considered none of the 36 lockages coming in sequence, gives us a very high resulting factor of safety.

GEO. F. CHISM.

APPENDIX K.

PRELIMINARY RECONNAISSANCES REGARDING STORAGE POSSIBILITIES OF THE UPPER OTTAWA RIVER WATERSHED.

It was decided to make a rapid reconnaissance of some of the Upper Ottawa lakes, and on May 18, 1906, Mr. F. G. Goodspeed, C.E., began a journey through the territory. He was accompanied by two guides and made the trip of 200 miles by canoe, from Kippewa via Ross lake to Grand Lake Victoria, thence up the main Ottawa, via Barriere to Kakabonga lake and down the Gatineau to Manikakl.

The party left head of Gordon creek, on Kippewa lake and proceeded through England bay to Hunter lake.

Kippewa lake is 110 square miles area and could be raised 6 feet, giving 660 square mile feet of storage. (See report of Mr. Brophy, 1905).

The route then taken was up Turtle portage to Hunter's Point, near the south end of Ostokonsing lake, which is 19 square miles area and could be raised 20 feet, giving 380 square mile feet of storage.

They then passed up the rapids into Birch lake and examined Meat Bird lake, then portaged up to Saseginata lake, and thence up to Ogascanan lake, a total rise of 134 feet above Kippewa. The area of Ogascanan lake is 10 square miles, and if the existing dam 70 feet long were raised 4 feet, making a total storage rise of 10 feet, then 100 square mile feet of storage could be obtained. The shores of the lake probably average 5 feet above present water (May, 1906). There are several swampy spots which, however, are only poorly timbered.

The next two lakes northward, but still in the Kippewa drainage area, are Brulé and Ross, which are held at the same level. Their combined area is 6 square miles, and they are closed by a lumber dam 80 feet long and 6 feet high, capable of storing 3,559 mile feet.

The local drainage area is small—3,059 miles—but if more territory can be drained in it is possible to raise the dam.

Portaging over the summit between Kippewa and the North Ottawa basin, the party descended Trout lake into Winawiaski. This last lake drains to the northwest, eventually reaching the main Ottawa. From the north end of Winawiaski is a portage 8 miles long to Old Man lake, which is almost the same level, and also empties toward the northwest through Spruce river. Old Man lake receives water from Old Woman lake, which is a summit pond and also empties northward by five rapids, falling 34 feet, into Fire Portage and Moose Horn lakes, and finally Grand Lake Victoria.

Grand Lake Victoria lies northwards across the interior basin, its northern arm, Twenty-one Mile bay, extends through Mink Narrows and drains a swamp area that sends water also toward Hudson Bay. It has a southerly arm, Eagle bay, stretching almost down to the head-waters of the Du Moine river.

Although long, Grand Lake Victoria is narrow and its area is only 25 square miles. The tributary basin includes all the Ottawa basin upwards to Kakabonga lake, an area of 4,000 square miles.

Grand Lake Victoria may rise 16 feet above its low water stage. It then includes Fire Portage and Moose Horn, which add 6 square miles to its area, making it in all (25 + 6) 31 square miles. Any further rise will cause a flow through Twenty-one Mile bay over the swamp toward Hudson Bay. The shores are generally high and rocky and the timber of little value.

Rabbit lake (Wapansanony) is roughly parallel to Twenty-one Mile bay and two to five miles west of it. Its surface is 26 feet lower. Grand Lake Victoria has two outlets into Rabbit lake. The area of Rabbit is 16 square miles, the west shore is very regularly about 10 feet above high water (June, 1906). Its outlet is the Main Ottawa, which flows from its north extremity where the shores become flat. An island divides the outlet into two streams.

The party continued up the Ottawa from Grand Lake Victoria through Awatan lake into Birch lake.

These lakes are 43 feet above Grand Lake Victoria, their area at the same elevation is 16 square miles, and a rise of 10 feet is practicable, giving 163 square mile feet storage.

The next expansion of the Ottawa is Backbone lake, which is not large. Below it the Shoshoguan river joins from the north, and above the Kapitajewan river.

Above Backbone lake there are two falls each nearly 30 feet, then Barriere lake, the surface of which is over 100 feet above Grand Lake Victoria. Barriere consists of two expansions joined by a short stream with a lumber dam that keeps the south pond high enough to flow toward the Gatineau, so logs can be floated out in that direction instead of following the circuitous route by Grand Lake Victoria and Timiskaming.

The party left the Ottawa river at Barriere and proceeded toward Kakabonga lake, which is a summit pond, draining east by the Gens de Terre river with the Gatineau river, and westwards over the Barriere lake dam down the Ottawa into Grand Lake Victoria.

The area of Kakabonga is made up as follows:—

	Sq. Miles.
(1) From Barriere dam to Narrows between Washkega and Kakabonga	9
(2) From Narrows to Back bay-Kakabonga lake	40
(3) Rapid lake up to dam on Wolf lake	12
(4) Back bay and Camp lake	12
Total	73

The territory drained is about 1,000 square miles, the principal tributary waters being Wolf lake, with its tributaries Awashemameka, Trout, Moose and Malawaskaga, The present surface is 280 feet, above Kippewa, and say 100 feet above Grand Lake Victoria. It could be raised 15 feet and if the Barriere dam were removed to the outlet of the north part of the lake and built across the main Ottawa, the new Kakabonga would have an area of 80 square miles and afford 1,200 square mile feet storage.

Wolf lake, mentioned above, has 10 square miles area, it is held 6 feet above its original level and, owing to flat shores, this cannot well be exceeded. It is 23 feet above Kakabonga, and its tributary Awashmameka is 10 feet higher, with an area of 8 square miles upon which a 3-foot layer could be stored, but the shores are flat and swampy above that height. Madawastagan lake, 4 square miles area, is at present held 6 feet above its original surface, so as to force its waters toward Windfall lake and down Tomasine for the log drive.

If the outlet of Windfall lake were closed by a dam 15 feet high then all this territory would drain to Kakabonga, whence the flood could be sent to Grand Lake Victoria.

Completing this reconnaissance of Kakabonga, the party descended its natural outlet, the Gens de Terre river, into the Gatineau, and examined Baskatong lake. This lake during spring freshets or even after heavy rains has no outlet, as the Upper

Gatineau rises faster than the lake which thus becomes a storage pocket. The maximum storage layer would be 10 feet, as a higher rise would flood Baskatong village.

This was the last reservoir visited, and the party passed down the Gatineau to Maniwaki and returned to Ottawa.

SECOND RECONNAISSANCE MADE BY MR. F. G. GOODSPEED, C.E.

After the information gained on the first trip was put together, it was deemed advisable to undertake a second journey across the Upper Ottawa drainage basin, passing this time, however, to the south of the former route. The starting point was again Kippewa lake, up which the party proceeded by steamboat, August 8, 1906, 45 miles to Red Pine chute. Thence by canoe up the Kippewa river to Bois Franc lake. This is 5 square miles area with good banks that admit of a 10-foot rise of surface.

Passing up river, Brennan lake was the next visited. It is an expansion of Kippewa river, area 5 square miles, with high well-timbered shores that allow a rise of 15 feet, giving 75 square mile feet of storage.

These is a rise of 100 feet along the Kippewa river from Brennan lake to Wolf lake, the Turner chute being 43 feet alone.

If Wolf lake is raised 12 feet, then Wolf, Brulé and Grassy lakes will form one reservoir, making 200 square mile feet of storage.

Leaving the Kippewa watershed, an examination of DuMoine lake was made and it was found that a dam at the foot, just above the Chute, holding the surface up 10 feet would be quite practicable and the resulting reservoir would have an area as follows:—

	Sq. Miles.
DuMoine lake, proper	30
Kippewa bay	6
Stubbs bay	7
Moose river, in part	2
Total	45

Alongside DuMoine river and 5 miles east of it is Ten Mile lake, area 7 square miles, which might be raised 15 feet, giving 105 square mile feet of storage. This lake drains into the DuMoine 3 miles below the Chute with a fall of 60 feet in 5 miles.

Leaving DuMoine lake at the north end of Stubbs bay, the route led into Bark lake, 10 feet higher, with an area of 7 square miles. It can only be raised 6 feet, however, as the shores are flat, but there is an upper Bark lake 25 feet above the other that can be raised 12 feet to store, say, 20 square mile feet in addition.

After considerable difficulty the party found a portage eastwards to Seven Mile lake and followed it down to Moose river. The lake area is 5 square miles and can be raised 15 feet, giving 75 square mile feet of storage. At the head of Moose river are two lakes called Big and Little Moose or Bell lake and Sucker lake, a 12-foot dam would make these one, with an area of 5 square miles, giving, say, 50 square miles storage.

There is a small canal cut through the height of land connecting Bay lake with Sucker lake mentioned above, so that logs can be sent down the DuMoine river instead of the long route by the Ottawa river and Timiskaming lake.

Bay lake could store a depth of 10 feet over its area of 15 square miles.

The party then crossed the head of the DuMoine basin eastwards to Little Victoria lake at the head-waters of the Coulonge. The area is 6 square miles and the height of the shores admits of a 12-foot rise, storing, say, 70 square mile feet.

Reaching the Coulonge river by Victoria creek, a trip was made down-stream to the outlet of Brulé lake. It is 60 feet above the river, emptying through a short rough

rocky creek. The area is 8 square miles and the shores are wooded with birch, pine and spruce, and high enough for a 15-foot rise, giving 120 square mile feet storage.

From the northeast end of Brulé lake, a portage was made to Nine Mile bay, a directly south arm of Giroux lake, which consists of three bays, the one mentioned and two others, aggregating 8 square miles in area, but a rise of 15 feet would include Nishcotea lake, making a united storage of 180 square mile feet. Nishcotea receives the flow from Big lake at the extreme northwest corner of the Coulonge basin. Around these lakes the pine is plentiful.

The route then taken was north from Nishcotea across the summit of the Coulonge basin into Round lake. This latter lake can be raised 15 feet, giving an area of 9 square miles at the new level. The shores are granite and there is an abundance of pine. The outlet is northward into Birch lake, an expansion of the Ottawa river, visited on the first trip. (See page 476.)

From Round lake there is a quarter-mile portage to Elbow lake (Indian-Odosguin, sometimes called Tea lake), which also drains into Birch lake. It contains 220 islands, and the shores are granite bluffs covered with fine pine that make it one of the most beautiful of the lakes visited. The area is 10 square miles and its surface can be raised 15 feet, giving 150 square mile feet storage.

A portage was made south into Caribou lake which lies between Elbow and Round lakes, and like them empties into Birch lake. Its shores are high and rocky with considerable pine still standing. The area is 8 square miles, and a rise of 15 feet may be possible, giving 120 square mile feet of storage.

Passing northeast up through a chain of small lakes, the party reached Chub lake, which receives the flow from Larouche and empties north into the Ottawa above Backbone lake, with a 50-foot fall. Chub lake is 7 square miles area and may be raised 15 feet, giving over 100 square mile feet of storage.

Portaging to the south, a lake of 5 square miles area called Dam lake was entered. Its water has been diverted south into Big lake by a small canal, as the drainage territory is only 50 square miles, its present rise of 5 feet is sufficient.

The route from By lake was south through a long narrow bay and then a portage out of the Coulonge basin eastwards into the Gatineau by a small lake leading into Trout or Moose lake. This drains by Awashemeka and Wolf lakes to Kakabonga. (See first trip, page 477.) The area is 15 square miles, and a dam 11 feet high would suffice for the 150 square miles of territory it drains.

Awashemeka is 18 feet lower than Moose lake, but its flat shores only allow of a 5-foot rise for its 10 square miles of surface, giving 50 square mile feet storage.

A portage was made to Madawastagan visited on the first trip. (See page 477.) It receives the flow from two lakes to the south (Island and Pike lakes), which are the same height, and one dam will suffice to raise both. Their area would be 15 square miles, and a 10-foot raise could be made, storing 150 square mile feet.

The third arm connected with Madawastagan is Windfall lake, 6 square miles area, which can be raised 15 feet, empounding 90 square mile feet. Surrounding the lake on all sides are high rocky hills and burnt country.

Tomasine creek flows from the southeast end of Windfall lake, through several small ponds, to Tomasine lake, 6 miles long by a quarter-mile wide. A 20-foot rise is possible, giving a storage of 40 square mile feet.

Continuing southeast Tomasine creek joins the Desert river at its head lakes Desert and Rond, which are practically the same level joined by a river stretch 4 miles long. Both lakes can be raised to form one pond area 15 square miles, including the river between and some marshes. There are five farms around Desert lake, but a rise of 15 feet is possible, storing 225 square mile feet.

The party then descended the Desert river 50 miles, to Maniwaki, arriving there September 20, after 37 days of arduous canoe travel.

APPENDIX L.

REPORT BY MR. F. H. PETERS, C.E., ON THE STORAGE POSSIBILITIES OF THE MONTREAL RIVER WATERSHED.

I have the honour to submit the following final report of the reconnaissance work carried out under my charge in the Montreal river water-shed during the past spring.

The following description of the party's movements and the methods of carrying out the work is an extract from my preliminary report of August 7th, 1907.

The party left Latchford, Ontario on May 28th, and proceeded up the Montreal river to the Matawapika river. At this point the party left the Montreal river and proceeded through Lady Evelyn lake and Diamond lake into the foot of Temagami lake, and carried elevations through to this point.

'The party then returned through Lady Evelyn lake and went up the Lady Evelyn river to its head-waters and portaged into Smoothwater lake, the head-waters of the East Branch, Montreal river.

'Along this route several tributary lakes of coonsiderable size were examined, and data gathered concerning their storage capacities. Smoothwater lake was reached on June 21st, and the party then proceeded down the East branch to its junction with the main stream near Fort Matachewan, which point was reached on June 30th.

' Camp was made here and the cook left in charge, while one canoe proceeded down the river to Latchford to purchase supplies. On returning from Latchford, camp was struck, and on July 8th the party started for the head-waters of the main branch Montreal river.

'These waters were all examined, and the party then returned to Latchford on July 27th, examining that part of the Montreal river between Fort Matachewan and the Matawapika river en route.

'The party went by train from Latchford to Temagami and three days were spent examining certain points on this lake.

'The party disbanded on August 3rd.

'The datum of levels was obtained at Latchford station from Temiscaming and Northern Ontario railway levels to Canadian Pacific railway datum. Elevations by hand level and water transfer were carried over the whole route traversed and as shown on the accompanying sketches, two large circuits were developed, namely: From Latchford via Lady Evelyn lake to Temagami lake and return via Temiscaming and Northern Ontario railway to Latchford; and from Latchford through Lady Evelyn river, east branch and main branch Montreal river, back to Latchford. Throughout the entire route all streams of considerable size were gauged; all possible storage basins traversed, and areas calculated, and dam sites cross-sectioned at all points where they might possibly be required. As much information as possible regarding high and low water fluctuations was gathered, but owing to sparsity of settlers along the route this was difficult.'

The aim has been to raise the water surfaces in reservoirs only to such a height as will not flood out any valuable timber. In some cases, considerable areas of spruce timber will be harmed but as it was impossible to determine their areas no estimate of their value has been attempted.

The type of dams, with one exception, is the ordinary lumberman's rock-filled crib dam with a constant width of twenty feet (20 ft.). For the quantities the profile areas were plotted and measured in each case from actual levels taken on a centre

line section. The quantities were then taken out for a solid dam, without openings, and estimated at $3.50 per cubic yard. This, it was assumed, would include the cost of stop-log openings and whatever shallow excavation was necessary. In Duncan's lake reservoir dam, some extra rock fill and earth excavation was necessary. In this case rock-fill was estimated at $1.50, and earth excavation at 40 cents per cubic yard.

Although gaugings of all streams of considerable size were taken it was not found possible to estimate, with any great degree of accuracy, the freshet run offs from the various catchment areas with these single gaugings. For this reason the run-offs from similar rivers, about which more information had been gained, were looked into. From these sources and from gaugings taken on the Montreal river, a run off of 2·7 cubic feet per second per square mile for the freshet period of 75 days, April 15th to June 1st appeared to be near the truth, and this was taken as the basis of calculation.

It has also been assumed that regulating works will be established at both outlets of Temagami lake and that the greater portion of its freshet waters will be passed through its northern outlet into Montreal river.

The total area of Montreal river watershed above Latchford (including Temagami), was found to be 2,732 square miles. Taking the freshet discharge at 2·7 cubic feet per second per square mile, we find total discharge = 47,796,480,000 cu. ft. From figures given in the table below the total storage capacity is 20,207,121 cu. ft. That is ·42 per cent of the freshet water can be conserved.

This would require eighteen (18) dams and consequently eighteen (18) reservoir basins. The total cost of these would be $125,107.00.

On pages 482 and 483 is given a tabulated list of levels taken, giving the elevations noted and also high water elevation over the whole watershed of the Montreal river. These levels are reduced to datum, mean tide New York, from Temiscaming and Northern Ontario railway levels at Latchford, Ontario.

Accompanying this report is a map of the Montreal river watershed on which are noted the positions of dams, (numbered to correspond with sheet 6) and also elevations of natural high water at various points. (Map not published.)

The areas of reservoirs were in most cases scaled from existing maps. But during the work the maps were studied carefully day by day and wherever large errors were observed from the canoe, they were noted and corrected later in the office before measuring the areas. Also the estimation of reservoir areas was in every case conservative, so that all reservoir capacities are probably on the low side.

MONTREAL RIVER RECONNAISSANCE, 1907.

Corrected levels, datum mean tide, New York.

Locality.	Area.	Elevation raised H. W.	Storage Head.	Reservoir Capacity.	Cost of Dam.
	Sq. Miles.	Feet.	Feet.	Thousands Cubic Ft.	$ cts.
1. Okawakenda lake	1·8	1,258	3	150,000	2,340 00
2. Lake S	2·6	1,255	3	224,000	500 00
3. Pigeon lake	2·1	1,154	7	418,387	15,990 00
4. Duncans lake	2·9	1,139	10	819,491	3,909 00
5. 2nd expanse above Great North Bend	2·2	1,129	7	420,159	3,341 00
6. 1st expanse above Great North Bend.	3·5	1,091	10	980,992	11,180 00
7. Fort Matachewan	1·5	1,040	10	421,075	10,790 00
8. Mountain chute	5·6	954	6	936,614	11,960 00
9. Bay lake	4·6	936	6	769,443	10,400 00
10. Smoothwater lake	3·9	1,281	10	1,086,880	8,320 00
11. Above rapid (8), east branch	3·1	1,122	5	439,090	4,030 00
12. Florence lake	8·1	1,238	3	676,608	2,847 00
13. Grays lake	1·7	1,212	3	142,800	4,680 00
14. Willow island lake	2·35	977	6	393,085	11,466 00
15. Temagami lake, north end	85·1	994	3	7,087,355	3,139 00
16. Temagami lake, south end	85·1	994	3	....	2,080 00
17. Diamond lake	3·8	990	10	1,059,379	8,125 00
18. Above Metawapika falls	15	970	10	4,181,760	10,010 00
Total	....	....	....	20,207,121	125,107 00

MONTREAL RIVER RECONNAISSANCE, 1907—*Continued.*

Locality.	Difference in Elevation.	Elevation noted.	Water Surface H.W.	Remarks.
	Feet.	Feet.	Feet.	
Base of rail T. & N.O. bridge, Latchford, Ont.	....	947·77	....	
W. S. Bay lake, May 28	−13·14	934·63	934·63	929·67 July 29.
Foot of Pork rapids	+ 0·20	934·83	934·83	
Head of Pork rapids	+ 7·30	942·13	942·13	
Foot of Squirrel rapid	+ 0·20	942·33	942·33	
Head of Squirrel rapid	+ 1·00	942·33	942·33	
Foot of Matawapika falls	+ 0·30	943·63	943·63	938·33 July 27.
Head of Matawapika falls	+23·16	966·79	966·79	960·79 July 27.
Lady Evelyn lake	+ 0·20	966·9	966·9	
Diamond lake	+12·9	979·8	980·8	
Temagami lake	+13·50	993·39	993·39	Check Temagami station.
Circuit Latchford, Montreal river, Temagami lake, T. & N.O.	....	....	....	Checks to 2·39.
Lady Evelyn lake	....	966·99	....	
Willow island lake	+ 4·83	971·8	972·0	
Head 1st fall above Willow island	+24·0	996·0	996·0	
Head 2nd fall above Willow island	+37·2	1,033·2	1,033·2	
Head rapid	+ 2·5	1,035·7	1,035·7	¼ mile above 2nd fall.
Head 3rd fall	+76·4	1,112·1	1,112·1	
Head rapid	+ 8·0	1,120·1	1,120·1	¼ mile above 3rd fall.
Head 4th fall	+14·8	1,134·9	1,134·9	Expanse head W. island.
Head 2nd expanse	+ 1·0	1,135·9	1,136·2	
Above ¾ mile portage	+32·1	1,168·0	1,168·4	Camp (6).
Mouth of Grays creek	+ 6·7	1,174·7	1,175·22	
W. S. Grays lake	+35·0	1,209·7	1,210·7	Judged by eye.
Mouth of Grays creek	....	1,174·7	1,175·2	
Head rapids 1 mile up	+ 6·8	1,181·5	1,182·0	
Head of rapids	+ 3·5	1,185·0	1,185·5	Go 200′.
Head next rapids	+ 8·0	1,193·0	1,193·6	Go ½ mile.
" "	+ 3·1	1,196·1	1,196·8	Go 500′.
" "	+ 4·8	1,200·9	1,201·6	Go 400′.
" "	+ 7·0	1,207·9	1,208·7	Go 300′.
" "	+12·0	1,219·9	1,220·7	Camp (8).
Current for ½ mile	+ 0·3	1,220·2	1·221,1	¼ mile above Camp (8).
Double rapid	+ 5·5	1,225·7	1,226·6	
6 M. of current at 6/10 per	+ 3·6	1,239·3	1,230·3	Camp (9).
Double rapid	+ 6·0	1,235·3	1,236·2	
Florence lake	+ 0·6	1,235·9	1,236·9	
W.S. foot Florence creek drop	+ 0·4	1,235·0	....	
Head 1st rapid above Florence	+19·2	1,254·2	1,255·7	
Head 2nd " "	+ 4·4	1,258·6	1,260·1	
Head 3rd " "	+ 2·0	1,260·6	1,262·1	
Head 4th " "	+ 5·0	1,265·6	1,267·1	
W.S. (Camp 11)	+ 7·5	1,273·1	1,274·6	Current 5 M. at 15.
W.S. Portage lake	+ 5·0	1,278·1	1,280·1	
W.S. Apex lake	+24·7	1,302·8	1,304·8	Summit.
Smoothwater lake	−30·6	1,272·2	1,273·7	June 22nd.
Smoothwater lake	....	1,271·9	1,273·7	June 24th.
Foot 1st rapid	−49·5	1,222·4	1,223·9	
Head of 2nd rapid	− 2·0	1,220·4	1,221·9	
Foot of 2nd rapid	−18·3	1,202·1	1,203·6	
Head of 3rd rapid	− 5·3	1,196·8	1,198·3	400′ rapid and current.
Foot of 3rd rapid	− 9·1	1,187·7	1,189·2	
Head of 4th rapid	− 0·5	1,187·2	1,188·7	
Foot of 4th rapid	−26·9	1,160·3	1,161·8	
Head of 5th rapid	− 1·0	1,159·3	1,160·8	
Foot of 5th rapid	−27·1	1,132·2	1,133·7	
Head of 6th rapid	....	1,132·2	1,133·7	
Foot of 6th rapid	− 3·6	1,128·6	1,130·1	
Head of 7th rapid	....	1,128·6	1,130·1	
Foot of 7th rapid	−11·5	1,117·1	1,118·7	Lake camp (16).
Head of 8th rapid	− 0·2	1,116·9	1,118·6	
Foot of 8th rapid	− 7·4	1,109·5	1,111·3	
Head of 9th rapid	....	1,109·5	1,111·3	
Foot of 9th rapid	−16·9	1,092·6	1,194·5	
Foot of 10th rapid	− 2·0	1,090·6	1,092·6	
" 11th rapid	−10·0	1,080·6	1,082·6	
" 12th rapid	−22·4	1,058·2	1,060·2	
" 13th rapid	−22·3	1,035·9	1,037·9	
" 14th rapid	− 2·0	1,033·9	1,035·9	
" 15th rapid	− 4·0	1,029·9	1,031·9	
" 16th rapid	− 1·3	1,028·6	1,030·6	
" 17th rapid	− 9·0	1,019·6	1,023·1	W.S. at Rangers.

MONTREAL RIVER RECONNAISSANCE, 1907—*Continued.*

Locality.	Difference in Elevation.	Elevation noted.	Water Surface H.W.	Remarks.
Camp junction of Main river, June 29.	Feet.	Feet.	Feet.	
Junction, Main river	....	1,017·8	1,023·1	Rangers camp, July 23.
Head of Fox rapids	....	1,017·8	1,023·1	
Foot of 7 mile rapids	−43·2	974·6	979·6	
Head of Indian chute	....	974·6	979·6	
Foot of Indian chute	−26·8	947·8	952·8	
Head of Mountain chute	....	947·8	952·8	
Foot of Mountain chute	− 7·4	940·4	945·4	
Head of Mountain	....	940·4	945·4	
Foot of Mountain	− 1·9	938·5	943·6	W.S. July 27.
W.S. foot Matawapika falls	....	....	....	Fall in W.S. 5·1.
Rangers camp	....	1,018·6	1,023·1	July 8th.
Head rapid	+ 3·0	1,021·6	1,024·6	½ mile above.
Head rapid	+ 7·0	1,028·6	1,031·6	1 mile below Matachewan.
Head rapid at Matachewan	+ 1·9	1,030·5	1,033·5	
Foot fall, Great North Bend	....	1,030·5	1,033·5	
Head fall, Great North Bend	+41·2	1,071·7	1,075·7	
Head of swift	+ 0·5	1,072·2	1,076·2	1·3 miles above G.N.B.
Head rapid No. 1	+ 9·1	1,081·3	1,085·3	Above Great N.B.
W.S. Camp (20)	+ 0·5	1,081·8	1,085·3	
Head rapid No. 2	+ 4·2	1,086·0	1,089·0	
Head rapid No. 3	+ 5·6	1,091·6	1,094·6	
Foot rapid No. 4	+ 1·0	1,092·6	1,095·6	
Head rapid	+13·4	1,106·6	1,109·0	
" No. 5	+ 4·0	1,110·0	1,113·0	
" No. 6	+ 7·5	1,117·5	1,120·5	Camp (21).
" No. 7	+ 3·0	1,120·5	1,123·5	
" No. 8	+ 4·0	1,124·5	1,127·5	
Foot rapid No. 9	+ 4·0	1,128·5	1,131·5	Camp (22).
Duncans lake	....	1,128·5	1,132·5	
Pigeon lake	+18·2	1,146·7	1,148·6	
Foot rapid No. 10	+ 1·0	1,147·7	1,149·7	
Head rapid No. 10	+ 7·4	1,155·1	1,157·1	
Head rapid No. 11	+ 3·5	1,158·6	1,160·6	
Head rapid No. 12	+ 2·5	1,161·1	1,163·1	
Foot rapid No. 13	+ 0·5	1,161·6	1,163·6	
Head rapid No. 13	+ 3·0	1,164·6	1,167·6	
Head rapid No. 14	+10·4	1,175·0	1,177·0	
Foot rapid No. 15	+ 0·5	1,175·5	1,177·5	
Head rapid No. 15	+14·1	1,189·6	1,191·6	
Foot rapid No. 16	+ 0·7	1,190·3	1,192·3	
Head rapid No. 16	+ 6·0	1,196·3	1,198·3	
Head rapid No. 17	+ 9·0	1,205·3	1,207·3	
Foot rapids below camp (24)	+ 0·8	1,206·1	1,208·0	
Head rapids below camp (24)	+10·0	1,216·1	1,218·1	
Head rapid at camp (24)	+ 4·0	1,220·1	1,222·1	
Lake G	+27·0	1,247·1	1,248·6	Five rapids.
Lake B	+ 0·4	1,247·5	1,249·0	
Lake S	+ 4·0	1,251·5	1,254·5	
Lake O, Kawakenda	+ 3·5	1,255·0	1,257·0	

APPENDIX M.

PRELIMINARY RECONNAISSANCES REGARDING STORAGE POSSIBILITIES OF THE GATINEAU RIVER WATERSHED.

A. J. Matheson, August 13, 1908.

Big Kegama lake north of the Pickanock river, has an area of about 3·4 square miles. The shores are high and would stand a raise of 20 feet without doing much damage. This year the water was raised 8 feet by a lumberman's dam at the foot. The dam is about 10 feet high and 100 feet long, but is on a poor sandy foundation and requires constant care to keep it from washing out. At present the flow from the lake is about 50 cubic feet per second.

Little Kegama lake is about 3½ miles south of Big Kegama lake. The creek connecting the two is very crooked and has several ponds on its course. Its length is about 10 miles, with a sand and gravel bed. There are no falls nor rapids, but there is a slope of about 15 feet in the total distance and the water is rapid.

The area of Little Kegama is about 2 square miles and the shores are high and rocky. There is a lumberman's dam at the lower end, about 8 feet high and 50 feet long, on rock foundation. This could be raised to 15 or 20 feet without material damage. There is only one house, which is at the upper end of the lake.

All the spring flow from both lakes could be retained in the Little Kegama by a dam about 15 feet high and 50 feet long, and discharged into the Pickanock river later in the season.

Lac Dumont empties into the Pickanock river from the north side about 35 miles from its mouth. The lake is about 7 square miles in area and the shores are steep. There is a lumberman's dam at the lower end, about 9 feet high, 50 feet wide at bottom, and 120 feet long on top, with a 15-foot stop-log opening. The dam is on rock foundation on the east bank, but the centre and the west bank is boulders and gravel. It could easily be raised without doing much damage, to a height of 15 or 20 feet, which would hold all the spring water. There is a fall of about 200 feet between Lac Dumont and the Pickanock river. The Little Dumont, which is between the two, is at present held by a lumberman's dam 8 feet high and could not be raised without flooding surrounding country to some extent. The larger lake is sufficient for storage purposes. The stop-logs were put in August 10, to collect the water for next spring in Lac Dumont.

The Pickanock river rose 8 feet at some points this spring.

Squaw lake, which is about 2·3 square miles in area, empties into the Pickanock river from the south side about 3 miles west of Dumont river. There is a lumberman's dam at the foot of the lake about 8 feet high and 100 feet long on rock foundation. This could be raised to 12 or 15 feet, which would hold all the spring water without doing much damage. A low side dam about 50 feet long would also be required to shut off a by-pass.

Lake La Peche, at the head of the Peche river, has an area of about 3 square miles. There is a lumberman's dam at the foot of the lake now a few feet high on a good boulder foundation. This dam could be raised without material damage to a height of 10 or 12 feet to hold all the spring water. At low water the Peche river is practically dry.

August 21-26, 1908.

Lake Couagama, which has an area of about 3 square miles, empties into Pythonga lake. At the foot there is a lumberman's dam 37 feet high and about 200 feet long on rock foundation.

Pythonga lake has an area of 8·5 square miles and empties by Hibou creek into the Eagle river on the north side. At the foot of the lake it is sandy, but there is a lumberman's dam at the mouth of Hibou creek 4 feet high on rock foundation. This dam could be raised to about 15 feet, and would be about 200 feet long at the bottom and about 400 feet long on the top. It would hold all the spring water, according to Mr. Armstrong, the bushranger for the Gilmour Co., who built the present dam.

On Petewagaman lake, between the Gatineau river and the Gens de Terre, there is a lumberman's dam 8 feet high and 150 feet long on top, on rock foundation. The area of the lake is about 10 square miles, and this could be raised to 10 feet or 15 feet and hold all the spring water. Some of the smaller lakes draining into it are already dammed by the lumbermen.

The Gatineau above Petewagaman lake is flashy. After a heavy rain there is a sudden rise in the water. The spring flood runs off here in about two weeks.

On the east side of the Gatineau, a series of lakes with rapids between empty into Baskatong lake, which is the same level as the Gatineau. Silver lake, with an area of about 7 square miles, could be stored to a height of about 10 feet or 15 feet, with a dam 150 feet long, the foundation for which would be rock.

Below this there is a rapid emptying into Georges lake and then Lake Coganigog, both of which are comparatively small. They flow into Piscabosine or Baskatoshin lake, which has an area of about 6 square miles and could be raised 15 feet or 20 feet by a dam 80 feet long at the foot of the lake. The foundation is rock.

From Piscabosine lake to Lake Baskatong there is a fall of 25 feet or 30 feet along the Piscatosin river. Baskatong lake has an area of about 20 square miles and is the same level as the Gatineau and fluctuates with it. The Baskatong river connects the two and the current is sometimes reversed when the Gatineau rises. The Baskatong river is deep except at each end where there are sand bars; the bottom and banks throughout are of sand.

Baskatong lake was 17 feet higher this spring than it was on August 25, and this is about the limit to which it could be conveniently raised. To effect this a dam should be placed at the head of the Baskatong rapids on the Gatineau river, about a mile below the mouth of the Baskatong river. The rapids are over a granite boulder bottom, and the greatest depth at present is 3 feet in the canoe channel. The fall at present would be between 5 feet and 10 feet. Rock shows on the west bank at the foot of the rapids, and on the east bank about 800 feet above the head of the rapids, so possibly the boulders in the rapids may be near the rock surface. The banks at the dam site are of sand and gravel; the east bank being about 18 feet high and the west 25 feet to 30 feet high. Rock also shows about 800 feet from the dam site on the east bank. The river at this point is about 310 feet wide and the bottom is fairly level.

There are no rapids on the Gatineau above Baskatong for about 15 miles.

The Gatineau river backs up into Lake Joseph, a small lake on the east side of the river about 10 miles north of Maniwaki.

Between Gracefield and Maniwaki east of the Gatineau river is Grand Lake Commissionaire or 31-Mile lake, which has an area of about 22 square miles. At the south end of this is Penichangan lake, with an area of about 5·7 square miles, which flows into 31-Mile lake. There is a lumberman's dam at the foot of Penichangan, and a total fall of about 15 feet to 31-Mile lake. There is also a large number of small lakes emptying into 31-Mile lake.

At the north end of 31-Mile lake there is a lumberman's dam about 6 feet high and 60 feet long on rock foundation, with two stop-log sluices 8 feet and 12 feet in

length and 6 feet deep. This dam could easily be raised to 15 feet to hold all the spring flood without doing much damage.

Thirty-one Mile lake flows into Mitchell lake with a fall of about 5 feet below the dam. Mitchell lake empties through a short creek into Old Woman lake. At the foot of Old Woman lake there is a lumberman's dam on rock foundation about 35 feet long and 8 feet high, with a stop-log opening 8 feet by 8 feet, raising both lakes and giving a combined area of about 1·5 square miles. Below this dam there is a fall of about 10 feet to Round lake.

Round lake has an area of about 1·5 square miles, and at its foot there is a lumberman's dam 6 feet high and 40 feet long on top and 15 feet long on bottom, on rock foundation. This could be raised to 15 feet. Below the dam there is a short creek leading to Rat lake, with a fall of from 25 feet to 30 feet.

Rat lake has an area of about 2·6 square miles and flows through Post creek into the Gatineau, with a fall of about 10 feet or 12 feet. There is no dam at the foot of this lake and every year the high water in the Gatineau backs up and raises the level of the lake about 10 feet.

The total fall from 31-Mile lake to the Gatineau is about 60 feet, and it would not be feasible to put a dam in the Gatineau to force the water up that much. All the local spring flow can be retained in these lakes with comparatively small dams.

The water in 31-Mile lake is sometimes raised 6 feet twice in a season.

The water surface of the Gatineau river at Maniwaki bridge on August 22, was 26 feet below coping of pier, or 24·5 feet below high water this spring.

APPENDIX N.

MR. R. W. FARLEY'S REPORT ON THE STORAGE POSSIBILITIES OF THE RIVER DU LIEVRE WATERSHED.

In the matter of regulating and controlling the flow of the River du Lievre, I beg to report as follows:—

As I previously informed you, I was during the season of 1904-06, employed to investigate the possibility of using the large lakes at the head-waters of this river as storage reservoirs for the purpose of equalizing the flow of this stream for power purposes. The results of my investigation and enquiries are to a large extent embodied in Schedule A, B and C., hereto annexed.

This river has a watershed of some four thousand and forty-three (4,043) square miles. The flow as measured by pneumatic meter at Buckingham, during a period of extreme low water in February and March 1905, I found to be one thousand seven hundred and sixty (1,760) cubic feet per second, and the flood flow may be taken as twelve thousand five hundred (12,500) cubic feet per second, but this latter extends for a period rarely exceeding a few days during the month of May.

The mean flow for a period of seventy-five (75) days, from the 1st of May to the 15th of July, may be taken as nine thousand (9,000) cubic feet per second. This river is used for power purposes and the flow could not be artificially reduced below some three thousand (3,000) cubic feet per second without causing serious complaint. Assuming, therefore, that six thousand (6,000) cubic feet per second can be stored this will mean 18½ square miles one foot deep per day or one thousand three hundred and eighty-seven and one-half (1387½) foot miles for the 75 day period.

I submit herewith tabulated statement of the principal lakes which can be used for storage purposes, together with their areas and approximate capacities. Schedule A.

The storage capacity of areas Nos. 1, 2, 3, 4, 5 and 6 as shown in Schedule A, is the calculated amount which can be collected during the autumn season, based upon the measured low water flow at the outlets of these lakes. See schedule C. For power purposes the storage basins have to be drawn upon during the dry period in summer and refilled during the autumn and it would be useless to create larger reservoirs than shown by this schedule. Where the object is to regulate the spring freshets a much larger capacity can, in certain cases, be provided, as shown by schedule B.

The question of damages by flooding of arable land or the destruction of valuable timber, together with the rights of settlers located in the vicinity of lakes and water courses was carefully considered in deciding the height to which dams should be erected and the elevation at which water could be held, and very little if any damage will be caused by creating the reservoirs shown in schedule A.

In the case of the increased pondage available at White Fish lake and Lake des Sables—Nos. 7 and 29—by placing the proposed dam upon the main river and immediately below the outlet of the former lake, a body of water containing 17,305 million cu. ft. or say 627 foot miles, will be created. This dam would be well down the river, being only some fifty (50) miles north of Buckingham, within easy communication by boat or telephone and any change in regulation thereof would be effective in the Ottawa river 24 hours after it was made.

At the point proposed for this dam the river bottom is rock and no serious difficulties should be encountered in constructing it.

It is true that a certain amount of arable land will be inundated but this will be trifling when the pondage thereby created, together with its other advantages, are considered.

There are no settlers in the vicinity of any of the other lakes mentioned in schedule C and no damage will be caused by the proposed dams.

I hand you herewith plan of the watershed of this river, as determined by limit surveys for the Department of Crown Lands, Quebec, showing the proposed location of the principal dams numbered to correspond with the schedules. A considerable portion of this territory is as yet imperfectly surveyed and a number of lakes exist which are not shown upon this plan.

SCHEDULE A.

Reference No.	Names of Lakes.	Area, Millions Sq. Ft.	Elevation of Dam above Low Water.	Storage Capacity Million Cu. Ft.
1	Coulotte and Nemiscachinque	610	9	5,490
2	Mejemangoos	302	12	3,790
3	Kiamika	180	7	1,260
4	Du Cerf	153·3	5	788
5	Serpent	55·8	22½	1,262·7
6	Des Ours	111·8	10	1,140·5
7	White Fish	613	15	9,185
8	Green, Croche and Rouge	96	8	788
9	Clay	46	8	388
10	Priest and St. Germain	28	8	224
11	Du Pins	20	10	200
12	Du Camp	30	8	240
13	O'Hara	27	8	216
14	Poche, Francois and Long	53	8	416
15	Rouges and Des Isles	177	8	1,416
16	Pike, Ecorse and Gauvin	150	8	1,200
17	Moreau	63	8	504
18	Des Cornes and Pike	85	8	680
19	Visson and Vicille	7	8	56
20	Brule, White-Birch	63	8	504
21	Porcupine and Windigo	58	8	464
22	Dog Fish	56	8	448
23	Tapanee	78	7	546
24	Waguabey	47	8	376
25	Red Pine	30	8	240
26	Echo	10	8	80
27	Windigo and Dore	112	7	784
28	Wazanasquahegan	179	8	1,432
29	Lake des Sables	110	8	880
		3,550·7—	1,252 ft. mls.	34,908·2

SCHEDULE B.

Reference No.	Names of Lakes.	Area, in Sq. Miles.	Elevation of Dam above Low Water.	Storage Capacity in Sq. miles, 1 foot deep.
1	Coulotte and Nemiscachinque	21·9	15	328·2
2	Mejemangoos	10·9	20	216·6
3	Kiamika	6·4	7	45·2
4	Du Cerf	5·4	5	28·3
5	Serpent	2·0	22½	45·3
6	Des Ours	4·0	15	60·1
7	White Fish	21·9	25	549·7
8	Green, Croche and Rouge	3·4	8	28·3
9	Clay	1·6	8	13·9
10	Priest and St. Germain	1·0	8	8·0
11	Du Pins	0·7	10	7·2
12	Du Camp	1·0	8	8·6
13	O'Hara	0·9	8	7·75
14	Poche, Francois and Long	1·9	8	14·9
15	Rouges and Des Isles	6·3	8	50·8
16	Pike, Ecorse and Gauvin	5·3	8	43·0
17	Moreau	2·2	8	18·1
18	Des Cornes and Pike	3·0	8	24·3
19	Visson and Vicille	0·2	8	2·0
20	Brule, White-Birch	2·2	8	18·1
21	Porcupine and Windigo	2·0	8	16·6
22	Dog Fish	2·0	8	16·0
23	Tapanee	2·7	15	42·0
24	Waguabey	1·6	8	13·5
25	Red Pine	1·0	8	8·6
26	Echo	0·3	8	2·85
27	Windigo and Dore	4·0	7	28·2
28	Wazanasquahegan	6·4	14	89·9
29	Lake des Sables	3·9	18	71·11
	Total			1,807·0

SCHEDULE C.

Low water discharge of the following lakes, measured at outlets, July and August, 1904.

1. Coulotte and Nemiscachinque, 700 cubic feet per second.
2. Mejemangoos 626 " "
3. Kiamika 162 " "
4. Du Cerf 162 " "
5. Serpent 116 " "
6. Des Ours 110 " "

SCHEDULE D.

Reference No.	Names of Lakes.	Natural Features.
1, 2 and 24....	Coulotte, Nemiscachinque and Waguabey.	These lakes are upon the extreme head-waters of the River du Lievre and close to the height of land, separating this river from the St. Maurice waters. There are no settlers in this section of country and little or no arable land in the immediate vicinity of the lakes. There is a considerable quantity of timber but little of it will be effected by holding water to height of proposed dams.
3...........	Kiamika........................	This lake is surrounded by an agricultural country, with a considerable number of inhabitants, but no damage will be caused by holding water to the height of the low dam, 7 feet, proposed.
4...........	Du Cerf........................	There are no settlers in the vicinity of this lake, and no damage would be caused by daming water to a much greater height than proposed, 5 feet. The west shore of this lake is, however, low and swampy and it would be impossible to hold the water to a greater elevation.
5...........	Serpent........................	There are two or three settlers upon the shores of this lake, and a few arces of their land will be inundated by proposed work, but the damage will be trifling; no timber will be effected thereby. There is very little arable land in the vicinity of this lake and the banks are high.
6.....	Des Ours........................	There are no settlers around this lake. The banks are high and mountainous and no arable land will be affected by proposed works.
7 and 29......	White Fish and Lake des Sables.....	There are a number of settlers around these lakes but the banks are, in most cases, high, and the amount of arable land inundated by the proposed works will not be great. A small saw-mill at the outlet of White Fish lake is operated during low water. During the spring floods water backs up from the river into this lake, cutting off power from the mill.
8...........	Green, Croche and Rouge............	There are one or two settlers around these lakes but they will not be effected by proposed works.
9...........	Clay............................	The land around this lake is all settled, but a dam already exists at the outlet and no damage will be caused.
10...........	Priest and St, Germain..............	There are a number of settlers round these lakes, but lumber dams already exist upon the outlets and no damage will be caused.
11 and 12......	Du Pins and Du Camp..............	There are settlers around these lakes, but the banks are high and no damage will be caused.
13...........	O'Hara........................	There are no settlers around this lake and no damage will be caused by proposed work.
14 and 15......	Poche, Francois, Long, Rouge and Des Isles.	The land around these lakes is practically all settled, but there are already lumber dams upon the outlets and the banks are high; no damage will be caused by proposed works.
16 and 17......	Pike, Ecorse, Gauvin and Moreau....	There are a number of settlers round these lakes, but the banks are high and very little arable land will be flooded by proposed works.
18...........	Des Cornes and Pike................	There are one or two settlers in the vicinity of these lakes, but little if any land will be flooded or damage done by proposed works.
19...........	Visson and Vicille..................	The banks of these lakes are hilly and very little land will be flooded by proposed dams.
20, 21 and 22...	Brule, White-Birch, Porcupine, Windigo and Dog Fish.	There are no settlers in the vicinity of these lakes; lumber dams already exist upon the outlets and no damage will be caused by proposed works.
23...........	Tapanee........................	There are no settlers in the vicinity of this lake; the banks are high, a lumber dam already exists thereon, and no damage will be caused by proposed works.
24, 25 and 27..	Waguabey, Red Pine, Windigo and Dore.	There are no settlers in the vicinity of these lakes; the banks are high and no damage will be caused by proposed works.
20...........	Echo........................	There are settlers round this lake, but the banks are high and little if any land will be flooded by proposed works.

APPENDIX O.

HANDLING OF BOATS IN RESTRICTED CHANNELS, CURVES, &c.

The following questions referring to the handling of boat traffic on the Great Lakes and to transportation generally were thoroughly discussed with Captain Norcross of the Wolvin fleet, one of the most experienced captains on the lakes. The fact that Captain Norcross is practically in charge of the fleet, owned by the Messrs. Wolvin of Duluth, Minn., shows the high esteem in which he is held, and great weight is attached to his opinion on matters relating to lake transportation. After full discussion of the questions put to him, he was kind enough to give in brief form his answers in writing.

Q. The Ottawa river route is not a canal but rather an improvement of the river. It therefore becomes necessary to have excavated channels in rock whose edges are out of sight below the water. What in your opinion would be the proper width for these channels for safe navigation of a modern lake vessel?

A. It has been demonstrated in all channels that we have dug in the United States for the acommodation of a 10,000 ton vessel, that 300 feet is as narrow a channel as can be used where vessels have to pass each other. In my opinion it is necessary to have a channel 500 feet wide to permit of steamers passing at full speed.

Q. The Stribling Point bend at the foot of Sugar island is the sharpest on the lake route, Duluth to Buffalo. Do you consider it safe to navigate this bend day and night?

A. I do. The fact that all our largest vessels are in the habit of navigating the Sault Ste. Marie river at all times night and day, and have never yet had an accident on this bend assures us that it is perfectly safe. This would also apply to the bend at the Sailor's Encampment. The only accident that has ever occurred at this point was caused by defective steering gear.

Q. These bends are made more difficult by a cross current, are they not?

A. Yes.

Q. Is it more difficult to make a bend to the left or to the right?

A. It is always more difficult with a large steamer to make a bend to the left because if one finds that after putting the wheel hard to starboard that the vessel is not going to make the bend without colliding with the opposite side of the channel it is impossible to back up, because in backing hard on the steamer the tendency to swing her stern to the left also, but in making a right hand turn if you find the steamer is not swinging fast enough it is easy to back, so reducing her speed and throwing her stern to the left, will bring her in line.

Q. We understand that it is the best, Captain, to have each leg of the channel marked by range lights, and in addition to this it would be a good thing to have small crib blocks at intervals placed close on the edge of the channel?

A. It would be a great advantage.

Q. When an island bars the channel would it not be better to fork the channel so that down-boats would pass on one side of the island and up-boats on the other.

A. Far better.

Q. The next matter is locks. What would you consider a proper size for the locks on this route?

A. I would suggest that you would build locks 800 feet long by 100 feet wide. In my opinion it is necessary to have some play for a large steamer entering one

of these locks; with a small vessel it does not do any harm if the steamer bumps the walls, but with 15,000 tons, taking the weight of the steamer and also the cargo into consideration, it would be a serious matter to collide with one of the walls.

Q. What is the practice as regards investment in lake steamers, namely, on what basis are they built and furnished to the owners?

A. The practice on fresh water in the United States of financing and building steamers is to form a company with a capital stock of about half or a little more than one-half the cost of construction. This capital stock is all paid in, and the balance bonded, the shipbuilding company taking all the bonds maturing them at the rate of ten per cent a year, the bonds to pay interest at five per cent.

Q. Has lake transportation from the owners' point of view proved a profitable investment?

A. Any first-class vessel from 7,000 tons upward paid stockholders ten to twelve per cent on the original investment, retired their ten per cent of bonds, paid the interest on their bonded indebtedness, and in a great many cases put ten per cent of the whole value of the vessel in a sinking fund.

Q. Therefore the rates that have existed heretofore have been fairly profitable.
A. Yes.

Q. Has there been any trouble in getting grain away from the upper lake ports?
A. No.

Q. Have you experienced trouble at Buffalo owing to the inability of the railways to take care of business and limited storage?
A. Yes.

Q. What do you consider the advantages of lake navigation from the head of the lakes to the seaboard?

A. The advantages of a through water route to the seaboard over a lake and rail route, would be a saving in rates and also time in delivery.

Q. What do you consider the advantages of this route as against the St. Lawrence route both on east and west bound traffic?

A. Grain can be carried from Port Arthur through the Georgian Bay Ship canal route at about 2 cents per bushel, in comparison it costs about 1½ cents at an average freight rate to Port Colborne, add to this a half cent for transfer, then allow 2½ cents freight to the 2,000 ton vessel which will have to carry it from Port Colborne to Montreal.

Q. What is the most satisfactory method of marking out the channel, by buoys, cribs, side banks or range lights, or by what combination of these?

A. Buoys and range lights and gas buoys on turns, cribs instead of buoys if possible.

NOTE.—Commodore Norcross considered that the least width of channel for safe navigation under the following conditions should be:—

	Single boats.	Boats passing.
(*a*) In rock above water	150 ft.	300 ft.
(b) In rock under water	200 ft.	300 ft.
(*c*) In earth above water..	150 ft.	300 ft.
(*d*) In earth under water..	200 ft.	300 ft.

In support of this he said: 'While it would be possible for a large vessel to navigate a hundred and fifty foot channel safely, if under slow steam, it would be dangerous to pass another vessel going in the opposite direction in less than three hundred feet because steamers and especially barges always take a sheer when passing, this being caused by the suction of the two vessels, and if when taking this sheer the stern should get close to the opposite bank in all probability it would be necessary to stop and back to swing the vessel into the channel again.

Q. What do you consider should be the least width of channel for safe navigation on curves?

A. It would depend on the abruptness of the curve. A vessel's stern should be at least 100 feet from the bank while her bow is following the centre of the channel around a curve, and double that distance if it is necessary to pass another steamer or tow.

Q. From the present indications what do you consider the smallest size of lock required to take any boat which would be likely to use the Georgian Bay Ship canal?

A. Length, 800 ft., breadth, 100 ft. and draft on sill, 23 ft.

Q. Is there any considerable inconvenience caused to boats at the upper entrance to the Canadian and American locks at the Soo owing to the current developed in filling the locks?

A. Very much inconvenience.

Q. Is there an undesirable current in these locks when being filled?

A. No.

Q. Is there an undesirable current in these locks when being emptied?

A. Yes.

Q. Is there an undesirable current below the lock when it is being emptied?

A. Not very.

Q. What fenders do you find most satisfactory along entrance pier?

A. Wood fenders on cribwork but not floating ones.

Q. Do you consider it necessary to have fenders in locks and if so vertical or horizontal, or both?

A. It is not necessary but desirable. If fenders are used they should be horizontal.

Q. What fenders do lake boats now carry?

A. The largest class carry none. Boats of 7,500 ton class carry horizontal fenders, but these will be done away with.

Q. What is the speed at which lake boats pass in dredged channels from 200 to 500 feet wide?

A. Boats can safely travel six miles an hour in dredged channels 200 to 300 feet wide. In a channel 500 feet wide they would travel full speed.

Q. What is the general tendency as to size of boat, that is length, width, and draft? What in your opinion will be the probable size of a common type of lake carrier for the next few years.

A. The general tendency for purely transportation companies is 9,000 ton class 545 feet long, 55 feet beam and 21 feet deep. The steel corporations build larger.

Q. How high should the top of mooring piers be above water?

A. About six feet.

Q. How far apart should mooring posts be?

A. One hundred feet.

Q. Why are floating fenders objected to?

A. Because being so narrow they bring the whole impact of the vessel on a narrow surface, and they also frequently turn edgewise.

Q. What is the quickest kind of a post to put lines on?

A. Any iron post that is above the level.

Q. Are the countersunk buttons as used in Montreal harbour liked?

A. No, these would not be liked for canal work.

Q. Is there a current above the Poe lock when the lock is filling?

A. Yes, there is a current and boats pull so hard on their lines that it is necessary to back the engines.

Q. What about fenders in locks?

A. There should be a rub timber along the walls to prevent the countersunk heads of plate rivets being worn down by the constant friction along the sides. A boat

that floundered last fall (1905) probably burst apart on a line of rivets that had been worn away. I have actually seen the wearing away of rivets on a boat that was locked.

Q. What about splay wall approaches to locks?

A. I think that the wall on the starboard side should flare at 1 in 10, say 60 feet flare in 600 feet length.

Q. Is there any surge in the Soo locks while filling and emptying?

A. In the American lock there is quite a surge, in the Canadian lock there is no surge, but in both locks the undergoing current drags down a boat. There have been no accidents.

Q. What will be the future size of lake boats?

A. They cannot be built much larger until the terminal facilities, docks, etc., have been improved. Boats will probably be 625 feet long by 70 feet beam. I think a boat of 7,500 tons all that is needed, say 480 feet long by 52 feet beam. Such a boat would require a lock 500 feet by 60 feet wide.

Q. What do you think of the future outlook of the Ottawa route?

A. If the round trip from Port Arthur to Montreal can be made in fifteen days it will completely revolutionize the transportation trade. A rate of 2 cents per bushel would be given to Montreal.

Q. Will not 21 feet be the governing draft indefinitely, through the St. Mary's river and between Lakes Huron and Erie?

A. I think 21 feet will be maximum draft for a great many years.

Q. Are the Lake Superior and Lake Erie harbours of sufficient depth to accomodate a draft, greater than 21 feet?

A. Harbours on Lake Superior will accomodate more, but not Lake Erie.

Q. Where a channel would be limited to say, 150 feet wide in rock, with straight sides and 22 feet deep for 20 foot draft, would additional depth to 5 or 6 feet under keel, permit better handling of vessels?

A. No, as vessel would have to be under slow speed.

Captain Norcross further gave his views on transportation and rates as follows:—

Taking wheat as a basis in 1905 the through sum of rate from the head of the Lakes to the sea-board via New York Central lines from Buffalo was five cents and via canal from Buffalo five and three-eighth cents. This is the lowest freight of the season. In the fall it went as high as ten cents via railroad lines and ten and one half cents via canal routes: the reason for the preferential in favour of the canal route was the assurance of no storage charges and the almost impossibility of securing cars from the railroad lines to deliver grain to the sea-board in time to make connections with the ocean sailings. These rates include all charges against the grain except when held in Buffalo in elevators for more than ten days, then the charge is one quarter of a cent in addition for every ten days or portion thereof. I might say here that the shortage of cars at Buffalo in the fall of the year is a very great inconvenience to the shipper on account of his not being able to always make connections with his ocean space. This would be practically eliminated if the Georgian Bay Ship canal route was in operation. If the Georgian Bay Ship canal were completed and capable of accomodating our largest and most modern freighters, wheat could be delivered at Montreal for two and one quarter cents per bushel. This would be allowing the steamer a very good margin of profit. If this canal is built according to the ideas suggested to me, by the engineers, it would be possible for a steamer to make the round trip from Port Arthur to Montreal and back to Port Arthur, returning without cargo in fifteen days, allowing four days to discharge at Montreal.

I am strongly of the opinion that should you construct the Georgian Bay Ship canal, the grain would only be one of a number of products that would be benefitted. The advantages and conditions applying to grain would also apply to all through freights, east and west bound.

NOTE—See plates 35 and 36.

APPENDIX P.

DATA RELATING TO CHANNELS CONNECTING THE GREAT LAKES.

Prepared by Mr. S. J. Chapleau, A.M. Can. Soc. C.E., M. Am., Soc., C.E.

A review of the improvements to the channels connecting the great lakes, Superior, Huron and Erie, may be useful in formulating an idea as to the existing drafts therein, and also as to the possibilities of future development in that direction.

The first improvement to any of the connecting channels was made to overcome the St. Mary's rapids in the river of that name, or what was then called the 'Sault Ste. Marie.'

These rapids are about three-quarters of a mile in length and half a mile wide, with a fall varying from 16 to 20 feet. The improvement consisted of a canal and lock built on the Canadian side by the Northwest Fur Company in 1797-98. The length of the lock was 38 feet, its width 8¾ feet, and overcame a lift of 9 feet. It was constructed of masonry with timber floor, gates and sills. The lock was situated at the foot of the rapids, the remaining fall in the rapids above being overcome by towing. It was destroyed in 1814 by United States troops.

Without touching further upon the very early history of transportation on the Upper Great Lakes, it may be said that the development of the connecting channels found its inception in the construction of the flight of two locks and the old canal above them at Sault Ste. Marie, Michigan, to overcome the 18-foot drop of the St. Mary's rapids at that point of the river, which formed the first link between the traffic of Lake Superior and that of the lakes below.

The old canal and locks were commenced on June 4, 1853, and the first boat was locked through on June 18, 1855. These locks were each 350 feet long, 70 feet wide, and a depth of 11½ feet water on the sills; the lift of each being 9 feet. The building of this lock was followed during successive years by the improvement of the harbours on the above lakes, by deepening and otherwise, until it became paramount that a deeper draft through the 'Soo' divide was necessary to accommodate not only the increased size of the lake carrier built and building, but also the enormous increase in lake traffic; the old locks being inadequate to cope with the demand made upon them for passage. This resulted in the construction of the Weitzel lock and canal, known then as now as the St. Mary's Falls ship canal; the name being retained during consequent improvement until we find it applied to the present high state of canal development on the Michigan side.

The contract for the construction of the Weitzel lock was dated October 20, 1870, the first stone of the lock was laid July 25, 1876, and the first boat locked through on September 1, 1881. The chamber of the lock is 515 feet long between quoins, 80 feet in width, narrowed to 60 feet at the gates. It has a lift of 18 feet (the full drop of the St. Mary's rapids), and a depth on sills of 17 feet; the sills being placed one foot below canal bottom for their protection from injury by passing vessels.

Up to this time the channel in St. Mary's river below the falls was along the International boundary to the east of Sugar island; this had been improved for a 12-foot draft from 1857 to 1869, and for a 16-foot draft during the interval 1879-1883.

With the completion of the Weitzel lock it became evident that the channel in the river below would in time prove unfit to accommodate the increasing traffic as it was

extremely tortuous, thereby difficult of navigation and required exceptional aids to navigation in the way of ranges and buoys for definition.

This resulted in the improvement, during the years 182 to 1894, of the Hay lake route, or the Middle Neebish channel to the west of Sugar island, to a depth of 20 feet at the mean stage of the Huron level below.

The same condition mentioned above, namely, the deepening of lake harbours and the building of larger lake carriers, together with the greatly increasing traffic which they engendered, forced the construction of the two additional locks at the Sault Ste. Marie rapids the Canadian lock and canal on the Ontario side, and the Poe lock (forming a part of the already constructed canal) built on the site of the original flight of two locks on the Michigan side of the river.

The Canadian lock is 900 feet in length between quoins in the chamber, 60 feet wide, and with 22 feet depth on the sills; it was commenced in 1888 and opened September 9, 1895.

The Poe lock is 800 feet in length between quoins in the chamber, 100 feet in width, and with 22 feet depth on the sills; it was commenced in 1887, and opened for traffic August 3, 1896.

With the increased dimensions of the new locks, when under contract, the shipping interests built to float a cargo commensurate with those dimensions and seemingly without regard to the immediate channels in St. Mary's river leading thereto, or the connecting channels which join lakes Huron and Erie, divining no doubt, that those channels would be so improved in time as to pass the draft defined by the sill depth on the new locks.

This led to the further improvement by deepening and widening of those connecting channels in St. Mary's river and since the completion of the Canadian and Poe locks a 21-foot depth of water at the mean stage of the Huron level has been obtained therein.

The river from the locks to the Huron level below had, in the original instance a definite fall of about 3 feet; its surface fluctuating with that of the lake. The deepening of the connecting channels therein increased the area of section—enlarged the weir as it were—which flattened the river slope and lowered the elevation of the w.s. at the foot of the rapids from what it had previously been during corresponding elevations of the Huron level.

The elevations of the lower sills, or more correctly the controlling elevations of the floors of the Canadian and the Poe locks, were determined by the lowest known elevation of the w.s. at the foot of the rapids at the time of building and apparently without regard to the effect of subsequent improvement in the river below.

The result has been that a less depth obtains on the floors of those locks than that for which they were designed, there being less than 19 feet upon them when the Huron level stands at the extreme low navigation stage. (Elev. 579·26).

Since 1897 the tonnage increase has been in excess of 300 per cent; this greatly increasing traffic demanded the development in 1903 of a new channel through what is known as the West Neebish, joining Hay and Mud lakes. This was completed during the past year and opened for traffic August 16, 1908; it assures the passage from the locks to the lake of 20-foot draft—21-foot depth—when Lake Huron stands at its lowest known monthly stage during the navigation season.

The improvement grades in the river above Lake Huron are calculated to afford that depth at that stage; or in other words, the grades are set 21 feet below the river slope that would obtain were the Huron level at elevation 579·0, which is 0·26 feet below the extreme low navigation stage.

Shoals in the river above the rapids have been removed to insure a like depth at the low stage of the Superior level.

The exceptional demands upon the locks occasioned by this increasing traffic, and to use the above channels to their full advantage, a new lock is projected and under contract on the Michigan side and will be known as the Davis lock.

It will be 1,350 feet long and 80 feet wide in the chamber, with a depth on sills of 24½ feet below the regulated stage above, and extreme low navigation stage below. The excess depth in the lock over that required for the draft, which is defined by the depth in the reaches below, is to facilitate the passage of vessels in and out of the lock.

The present canals above the lock on both sides of the river have a depth of 25 feet below a water surface elevation of the Superior level which can, and will be maintained at or above elevation 601·75 by regulating works above the rapids, and by control of the flow feeding the power canal on both sides of the river through agreement forced by the International Waterways Commission.

The upper approach to the new lock is designed for this depth below the same plane of the Superior level, elevation 601·75.

The depth of 25 feet through the canal approaches above is to allow for a sufficient depth for vessels waiting for lockage when the water surface drops therein during the filling of the chamber.

Improvements at the lower end of Lake Huron into the head of St. Clair river, at points along the river, and through the upper end of Lake St. Clair, have been made to a depth of 21 feet below, and across the St. Clair Flats of 20 feet below an improvement plane of elevation 581·6 which plane was adopted for the lower end of Lake Huron, with the water surface of the river, and of the Lake St. Clair corresponding thereto. The above elevation is 2·34 feet higher than that of the extreme low navigation stage, and 2·6 feet higher than the improvement plane used to determine the grades of the St. Marys river at the other end of the lake.

Should this extreme low navigation stage obtain, there would be but 18·7 feet depth in the channel at the lower end of Lake Huron into the St. Clair river and at points in that river; and but 17·7 feet across the Flats of Lake St. Clair.

It seems improbable that a greater depth through the above channels than 21 feet during the extreme low stage of the connected lakes will be undertaken. The improvements date from 1866 in Lake St. Clair to accommodate the 9-foot draft defined by the then completed locks—the old state locks—at the 'Soo.' They have continued since in that and the other channels, to the present time, to accommodate the increased drafts allowed by the Weitzel, and after, the Canadian and Poe locks; the drafts defined by the latter being as yet incomplete. The new Davis lock will pass, when completed a greater draft than before—24 feet—but to have that draft throughout, will require the channels through the St. Marys river, St. Clair river, Lake St. Clair and the Detroit river, deepened an additional 4 feet. This would be a stupendous undertaking, requiring many years to perfect and a vast outlay of money.

There are, moreover, few harbours on the Upper Lakes that can berth the draft of 21 feet during the extreme low stage at the present time, and their improvement to a depth of 25 feet would also, in itself, be an undertaking probably as great as that of the connecting channels.

It is a question if the depth of 21 feet cannot meet the demands of the lake traffic for the future; 20 feet draft at the extreme low stage means 22 feet to 23 feet draft at mean summer level and while each additional inch draft means 60 to 80 tons additional cargo—depending upon its nature—in the largest carriers, it would seem that the natural increase in the number of lake carriers with probable increased facilities at the Sault Falls in the way of more locks of the same present capacity, would suffice to pass an increasing traffic at less expense than by the deepening of the connecting channels.

Further deepening of the connecting channels, above referred to, will impose another condition. Increasing the section area of discharge of any channel of a definite slope will change that slope and tend to lower the surface of the basin above.

In the present case an increased area through the Huron to Erie stretch would affect the level of the former, not appreciably at first, nor suddenly at any time, but would be shown by gradually lower averages of the mean monthly elevation of the Huron-Michigan basin and consequently in time, of a lower extreme low navigation stage therein.

The effect of this on the harbours of Huron, the Georgian Bay and Lake Michigan would thus be felt in time, and perhaps seriously.

The discharge through the Chicago main drainage canal has its initial effect upon the Huron Michigan level, and the question of the amount that shall be drawn thereby is at present a question of international moment in which the shipping interests of the Great Lakes are much concerned.

This is referred to in a report of Charles E. L. B. Davis, Lieut.-Colonel Corps of Engineers, to the Chief of Engineers United States army, under date of April 10, 1905 as 'the only portion of the ship channel not yet provided for under the depth of 21 feet is the stretch covering Lake St. Clair, the St. Clair river, and the lower end of Lake Huron.' It is presumed that this portion of the connecting ship channels will be improved to a depth of 21 feet or more below a lake Huron improvement plane of 579·0, and corresponding surfaces of the St. Clair river and lake.

The Detroit river is under heavy improvement at the present time and the present channel, with the exception of Ballards Reef, has now a depth of 21 feet below an improvement plane of elevation 571·0, there being 19·2 feet depth below this elevation at the Ballards Reef, the first improvement below Lake St. Clair.

This improvement plane is 0·3 feet higher than the extreme low navigation stage of Lake Erie, and 1·8 feet lower than the improvement plane of Lake Erie harbours.

A new channel known as the Livingstone channel is now under construction in the lower Detroit river, from a point in the river above Amherstburg, Ontario, to deep water in the lake, which when completed will have a depth of 22 feet in earth, and 23 feet in rock below elevation 571·0.

It will be seen from the above that the limit of draft in the upper lakes is set by the prevailing depth in the channels at the lower end of Lake Huron, River St. Clair and Lake St. Clair, all being dependent entirely upon the stage of the Huron level.

It must not be inferred from the foregoing that 19 feet draft is the probable limit during the navigation season; a greater draft than that, possibly even up to 23 feet, may be possible during certain stages of the lake levels as it must be remembered that those stages absolutely control the depths in the artificial channels between.

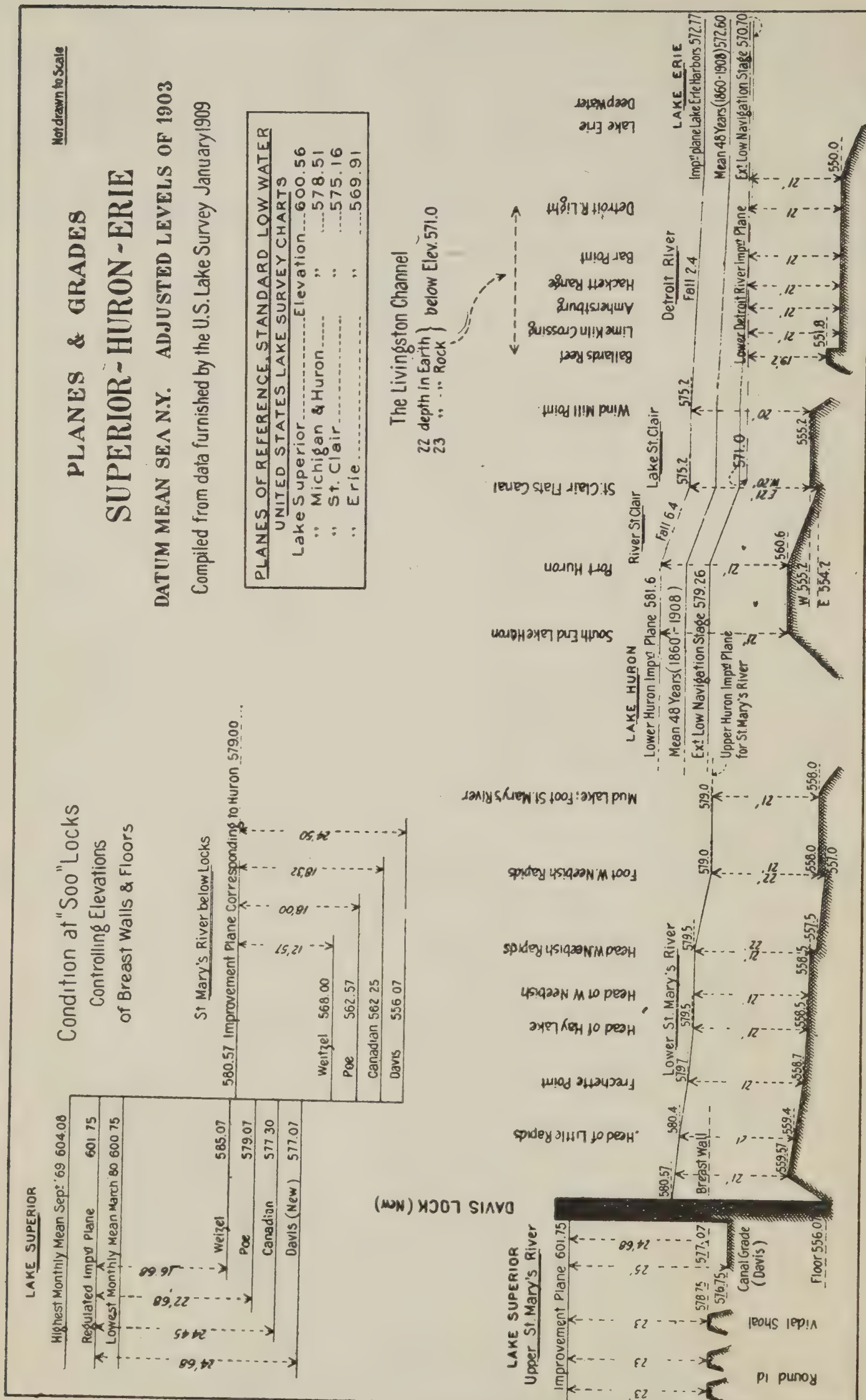
As to a future depth in the connecting channels between Lakes Erie, Huron and Superior, greater than that of 21 feet during extreme low stage which will eventually be completed, the following quotation from a report of Charles E. L. B. Davis, Lieut. Colonel, Corps of Engineers, United States army, to Brig. General A. Mackenzie, Chief of Engineers (under date of January 12, 1906), may be here given, in which he refers to the Livingstone channel in particular, and the connecting channels between the lakes in general:—'The depth of 22 feet is recommended for this channel because the future growth of commerce may warrant the expenditure necessary to secure an extra foot over the present depth (21 feet) while the cost of securing 25 feet in these channels and tributary harbours will probably be prohibitive, at least for many years to come.'

In order to present the existing condition of the connecting channels between the upper lakes, the depth through the 'Soo' locks, and the different improvement planes and water surfaces corresponding thereto, the profiles shown page 500 were compiled by Andrew J. Swift, Junior Engineer, United States Lake Survey, and the writer

from data furnished by the United States Lake Survey at Detroit, Michigan. The drawing is sufficiently broad to be self-explanatory.

With the exception of improvements on the Vidal shoal above St. Marys rapids to a depth of 23 feet, the construction of the Canadian lock and canal, and the improvements of the channels leading thereto, the work of improving the channels connecting the great lakes has been done wholly by the United States government under the direction of the Corps of Engineers of the United States army.

To Mr. F. C. Shenehon, Principal Assistant Engineer, and the officers of the United States Lake Survey, our indebtedness is gratefully acknowledged for aid and information and other courtesies extended.


PLANES & GRADES
SUPERIOR-HURON-ERIE
DATUM MEAN SEA N.Y. ADJUSTED LEVELS OF 1903
Compiled from data furnished by the U.S. Lake Survey January 1909
Not drawn to Scale
PLANES OF REFERENCE, STANDARD LOW WATER
UNITED STATES LAKE SURVEY CHARTS
Lake Superior .... Elevation ... 600.56
" Michigan & Huron ..... " ... 578.51
" St. Clair ..... " ... 575.16
" Erie ..... " ... 569.91
The Livingston Channel
22 depth in Earth } below Elev. 571.0
23 " " Rock
Condition at "Soo" Locks
Controlling Elevations
of Breast Walls & Floors
LAKE SUPERIOR
Highest Monthly Mean Sept '69 604.08
Regulated Impd Plane 601 75
Lowest Monthly Mean March 80 600 75
Weizel 585.07
Poe 579.07
Canadian 577 30
Davis (New) 577.07
St Mary's River below Locks
580.57 Improvement Plane Corresponding to Huron 579.00
Weitzel 568.00
Poe 562.57
Canadian 562 25
Davis 556 07
LAKE SUPERIOR
Upper St. Mary's River
Improvement Plane 601.75
DAVIS LOCK (New)
Breast Wall
Canal Grade (Davis)
Floor 556.07
Round Id
Vidal Shoal
Head of Little Rapids
Frechette Point
Head of Hay Lake
Head of W. Neebish
Head W. Neebish Rapids
Foot W. Neebish Rapids
Mud Lake; Foot St. Mary's River
Lower St. Mary's River
LAKE HURON
Lower Huron Impd Plane 581.6
Mean 48 Years (1860-1908)
Ext Low Navigation Stage 579.26
Upper Huron Impd Plane for St. Mary's River
South End Lake Huron
Port Huron
River St Clair
Fall 6.4
St. Clair Flats Canal
Lake St. Clair
Wind Mill Point
Ballards Reef
Lime Kiln Crossing
Amherstburg
Hackett Range
Bar Point
Detroit R. Light
Detroit River
Fall 2.4
Lower Detroit River Impd Plane
Lake Erie
Deep Water
LAKE ERIE
Impd plane Lake Erie Harbors 572.77
Mean 48 Years (1860-1908) 572.60
Ext Low Navigation Stage 570.70
J.E.R. Matte, Del.

APPENDIX Q.

NOTES REFERRING TO CHARTER OF THE MONTREAL, OTTAWA AND GEORGIAN BAY CANAL COMPANY.

Prepared by Mr. A. T. Genest, C.E.

An Act to incorporate this company was assented to July 23, 1894. (57-58 Vic. Chap. 103).

The petitioners were George Cox, McLeod Stewart, Gordon Burleigh Pattee, Henry Kelly Egan, John W. McRae, Thomas Birkett, Olivier Durocher, Alexander McLean, Francis McDougall, John Charles Roger, Dennis Murphy, Charles Berkeley Powell, John E. Askwith, Hon. Francis Clemow, Sir James Grant, M.P., Honore Robillard, M.P., Thomas Ahearn, George Patrick Brophy, Alexander Harvey Taylor, Peter Whelan, Richard Nagle, David MacLaren, William Scott, Joseph Kavanagh, Philip D. Ross, all of the city of Ottawa; William C. Edwards, M.P., of Rockland; William T. Hodgins, M.P., of Hazledean; Alexander Fraser, of Westmeath; James Joseph O'Connor, of Port Arthur; Joseph Martin, M.P., of Winnipeg; John Bryson, M.P., of Coulonge; George H. MacDonald, of Port Arthur; Hugh F. McLachlin and Claude McLachlin, of Arnprior; James Craig, of Renfrew; James Wm. Bain, M.P., of St. Polycarpe; Joseph Gédéon Horace Bergeron, M.P., of Montreal; and William Owens, of Lachute.

The first twenty persons named were the provisional directors of the company.

The capital stock of the company was ten million dollars divided into shares of one hundred dollars each.

The company has the right to issue and pledge or dispose of bonds, debentures or other securities to the extent of thirty million dollars.

The construction of the canals authorized to be constructed, or some of them, was to commence and fifty thousand dollars were to be expended thereon within two years after the passing of the Act, and the term of eight years was given to finish and put the work in operation.

The dimensions of the canals were to be such as to make and construct a navigable channel of at least nine feet in depth between the terminal points.

An Act to revive and amend the Act of 1894 was assented to October 5, 1896. (60 Vic. Chap. II).

Section 3 of the first Act was repealed and the following substituted therefor:—

'3. McLeod Stewart, Alex. McLean, Joseph Kavanagh, Alexander Harvey Taylor, Francis McDougall, David MacLaren, George Patrick Brophy, the Hon. Francis Clemow, William C. Edwards, William Hutcheson, Napoleon Antoine Belcourt, of the city of Ottawa; Thomas Mackie, of Pembroke; James B. Klock, of Klock's Mills; Claude McLachlin, of Arnprior; Charles Ramsey Devlin, of Aylmer; William John Poupore, of Morrisburg; Archibald Foster and William Murray, of Pembroke, and James Joseph O'Connor, of Port Arthur, together with such persons as become shareholders in the company hereby incorporated are hereby constituted a body corporate under the name of 'The Montreal, Ottawa and Georgian Bay Canal Company.'

The first six persons named were the provisional directors of the company.

Section fourty-four of the Act of 1894 was repealed and the following substituted therefor:—

'44. If the construction of the canals hereby authorized to be constructed, or some of them, is not commenced, and fifty thousand dollars are not expended thereon, on or before the first day of May, one thousand eight hundred and ninety-eight, or if the said canals are not finished and put in operation within eight years from the said first day of May, one thousand eight hundred and ninety-eight, then the powers granted by this Act shall cease and be null and void as respects so much of the said canals and works hereby authorized as then remains uncompleted.'

An Act respecting the Montreal, Ottawa and Georgian Bay Canal Company, assented to May 7, 1900 (63-64 Vic. Chap. 106), extended the time for the commencement of construction to May 1, 1900. Section 8 of chapter 103 of the statutes of 1894 and section 4 of chapter II of the statutes of 1896, were amended so as to include in the canals described therein, that part of the navigation comprised between the cities of Montreal and Ottawa.

An Act respecting the Montreal, Ottawa and Georgian Bay Canal Company assented to May 7, 1900 (63-64 Vict. Chap. 106), extended the time for the commencement of construction to May 1, 1900, and for the completion of the work to May 1, 1908. Section 5 of chapter 103 of the statutes of 1894 was amended by adding thereto the following subsections:—

'2. The directors of the company may pass a by-law for creating and issuing any part of the capital stock as preference stock, giving the same such preference and priority as respects dividends and otherwise over ordinary stock as may be declared by the by-law.

'3. The by-law may provide that the holders of shares of such preference stock have the right to select a certain stated proportion of the board of directors, or may give the said holders such control over the affairs of the company as may be considered expedient.

'4. No such by-law shall have any force or effect until it has been sanctioned by a vote of the shareholders representing at least two-thirds in value of the subscribed stock of the company, present or represented by proxy at a general meeting of the company, duly called for considering such by-law.

'5. Holders of shares of such preference stock shall be shareholders within the meaning of this Act, and shall in all respects possess the rights and be subject to the liabilities of shareholders within the meaning of this Act; provided, however, that in respect of dividends and otherwise they shall, as against the ordinary shareholders, be entitled to the preference and rights given by such by-law. Section 22 of chapter 101 of the statutes of 1904 was repealed and the following substituted therefor:—

'22. The company may issue and pledge, or dispose of bonds, debentures or other securities as provided in the Railway Act, to the extent of thirty-five millions of dollars.

An Act respecting the Montreal, Ottawa and Georgian Bay Canal Company assented to May 15, 1902 (2 Edward VII, chapter 79), extended the time for the commencement of construction to May 1, 1904, and for the completion of the work to May 1, 1910, but inserted the following clause:—

'2. The company shall not exercise its powers in respect of the section from Lake Nipissing to Georgian Bay, otherwise called 'The French River Section,' until and unless an order of the Governor in Council is passed authorizing the same.'

An Act respecting the Montreal, Ottawa and Georgian Bay Canal Company assented to June 6, 1904 (4 Edward VII, chapter 98), extended the time for the commencement of construction to May 1, 1906, and for the completion of the work to May 1, 1912.

An Act respecting the Montreal, Ottawa and Georgian Bay Canal Company assented to July 13, 1906 (6 Edward VII, chapter 128), extended the time for the commencement of construction to on or before the first of May, one thousand nine hundred and eight and for the completion of the work to May 1, 1914.

The company was authorized to raise its capital stock from ten million to fifty million dollars divided into shares of one hundred dollars each, and to issue and pledge or dispose of bonds, debentures or other securities to the extent of one hundred million dollars.

Section 43 of chapter 103 of the statutes of 1894 was repealed and the following substituted therefor:—

'43. His Majesty, His heirs and successors, may at any time, assume the possession of, and the property in, the said canals and works, and of and in all the rights, privileges and advantages of the company on giving to the company one week's notice of intention to do so; and thereupon all property in the said canals, works, rights, privileges and advantages shall become, and thenceforward shall be vested in His Majesty, His heirs and successors; and by way of compensation, His Majesty shall pay to the company, up to the time of the giving of such notice, in surveying and in the making of plans and otherwise upon the ground, together with the value of all tangible property of the company of which possession may be so taken,—such value to be fixed by three valuators, or the majority of them, one valuator to be chosen by His Majesty, another by the company, and the third by the two so chosen.'

The following Act respecting the company was assented to April 3, 1908 (7-8 Edward VII, chapter 130):—

(1) Section 4 of chapter 128 of the statutes of 1906 is repealed.

(2) The Montreal, Ottawa and Georgian Bay Canal Company may commence the construction of its canals or some of them, and expend fifty thousand dollars thereon, on or before the first day of May, one thousand nine hundred and ten, and may finish the said canals and put them in operation by the first day of May, one thousand nine hundred and sixteen, and, subject to the provisions of this Act, may, in connection with such construction and operation, exercise all the powers granted to the said company by its Act of incorporation, chapter 103 of the statutes of 1894, and amendments thereof; and if such construction is not so commenced and such expenditure is not so made, or if the said canals are not finished and put in operation, on or before the said respective dates, the powers granted to the said company by parliament shall cease and be null and void as respects so much of the canals and works of the said company as then remains uncompleted.

(3) Nothing in this Act shall affect or impair the rights of the government of Canada, under or by virtue of the provisions of the section substituted by section 5 of chapter 128 of the statutes of 1906 for section 48 of chapter 103 of the statutes of 1894.

APPENDIX R.

HISTORICAL NOTES OF THE OTTAWA VALLEY.

Compiled by C. R. Coutlee, M.Can. and Am. Soc., C.E.

INTRODUCTION.

An investigation of the Ottawa would be incomplete without some reference to the history of the development of the settlement of the valley and the origin of the commerce that has induced thousands of people to make their home and perform their life work in the district.

The valley represents a bay or inlet of a very ancient geological sea, which covered everything to the south, and washed the bold gneissic shores—now known as the Laurentian hills—along the north, while the southerly shore of the inlet was the granite ridge, which crosses Ontario from Portage du Fort to Brockville and forms the Thousand Islands of the St. Lawrence.

The present town of Mattawa represents the head of this inlet, thence up Lake Timiskaming to the Cobalt mining region was probably 'a defile or narrows,' connecting the main sea with an interior basin. See plate 3.

The floor of this interior basin is from 800 to 1,000 feet above the present Atlantic, and Grand Lake Victoria is its centre.

The sources of the Ottawa and the upper 300 miles of its length lie in this interior basin. It is a granitic area, thickly wooded with pine, spruce and hardwoods, and dotted with numerous lakes. There are only a few isolated farms, upon which oats, hay and potatoes are raised in connection with the lumber industry.

The discoveries of mineral at Cobalt and railway extension northward have created thriving settlements within the last few years, however, at the head of Lake Timiskaming, and thence southward to Mattawa.

From Mattawa the river, now half a mile in width, flows due east for fifteen miles to the head of a series of rapids at Deux Rivières village. Both shores are rocky and, on the north, the river may almost be said to flow along the foot of the Laurentian chain.

Below Deux Rivières is another river stretch of fifteen miles, broken by several rapids and finally plunging down the Rocher Capitaine. The next stretch, bordered by bold bluffs like a western cañon, leads to Des Joachims falls, which complete the descent of 135 feet from Mattawa to the surface of Deep river.

Deep river extends, in an almost direct line for forty-five miles, to Pembroke The north shore is a bold chain of hills 500 to 1,000 feet above the water, the most prominent being Oiseaux rock, whose echo responded three centuries ago to the song and shout of the fur trader. The lower end of Deep river divides around the north and south of Allumette island. The north branch is known as the Culbute, and the south is Pembroke lake in front of Pembroke. A small rapid, at Morrison island, connects this lake with Allumette lake in front of Westmeath, and it, in turn, empties through the Paquette rapids into Lake Coulonge, where it is rejoined by the Culbute or north branch. Coulonge lake extends about twelve miles to Coulonge village, where the stream divides again into a north and south branch around Calumet island. The north branch leads by a sandy channel to Bryson, where it descends by the Calumet falls. The south or Rocher Fendu branch

leads, by some twenty rapids or falls, to rejoin the northern one, about five miles above Portage du Fort.

The Portage du Fort rapids are chiefly above Limerick island; below, the river flows between high rocky banks to the Chenaux rapids, which fall one to four feet into the head of Arnprior lake. This lake, 16 miles long and 4 wide, lies in front of the town of Arnprior, its surface being one hundred feet below Coulonge lake.

At the foot of Arnprior lake, are the Chats rapids, pouring over a rocky ridge into Deschenes lake, which extends twenty-seven miles down to Deschenes rapids. On both banks the land has been cultivated for many years.

From Deschenes down for eight miles, is rapid water, culminating in the Chaudiere falls, the descent being altogether sixty feet.

Below the city of Ottawa, is an uninterrupted river reach sixty miles long, ending at Grenville and Hawkesbury, whence there is a continuous rapid for five miles to Greece Point. From Greece Point to Carillon is a still basin, artificially maintained by the Carillon dam. The fall between this basin and the lake of Two Mountains or Oka lake is overcome by the Carillon canal, built by the Royal Engineers about 1830. See page 517.

Oka lake is twenty-five miles in length,—the last reservoir of the whole Ottawa system. It extends from Carillon and Point Fortune past Hudson and Oka villages to Ste. Anne and St. Eustache.

The connection between the waters of the Ottawa and those of the St. Lawrence is made by four branches:—

The most westerly is the Vaudreuil branch, separating the mainland from Ile Perrot.

Next, the Ste. Anne branch, separating Ile Perrot from Montreal island.

Then the Back river, separating Montreal island from Ile Jesus, and, lastly, the St. Eustache branch, separating Ile Jesus from the mainland.

EARLY VOYAGEURS—1600-1700.

In 1600, the Rideau, South Nation and Rigaud river valleys were occupied by Algonquins. The so-called Petite Nation division of this tribe occupied the vicinity about Papineauville. The Grand Nation division inhabited Allumette island.

Samuel Champlain left Montreal (1613) and proceeded up the Ottawa to Allumette island, remaining some days with Chief Tessoüat, who had a village and cultivated gardens near the present site of Pembroke. It was decided not to embark in any wars that season, so the French returned to Montreal. In 1615, however, Champlain, accompanied by eight white men, passed up the Ottawa to Mattawa, thence to Lake Nipissing and down the French to Georgian Bay and by the Trent valley to Lake Ontario.

Paul Maisonneuve founded Montreal 1642.

Nicolas Gatineau dit Duplessis, lived at Three Rivers and traded up the St. Maurice and down the Gatineau river, 1650.

In 1660, the Ottawa river was deserted by writes from Oka lake to Nipissing, and was under the domination of the Iroquois. They had systematically driven out all other tribes, to secure the monopoly of the beaver catch, which they sold at Albany on the Hudson.

By the treaty of 1669, they were still at liberty to hunt over the district, but this was stopped in 1683 and never resumed. Nevertheless, till 1697 they constantly attacked traders. Fights took place at Carillon, L'Orignal, Calumet, Rideau falls, Chaudière falls, Deschenes lake, Calumet island and Lake Nipissing between 1684 and 1697. Dollard's fierce fight was to intercept a foray of these savages upon Montreal and the ferocious massacre of Lachine, August, 1689, was another evidence of the Iroquois fury.

Francois Marie Perrot married a daughter of intendant Talon and was governor of Montreal in 1670. He obtained a grant of Ile Perrot and became a lawless pirate. He was placed in the Bastille, 1674, but afterwards resumed his evil practices.

Capt. Jacques Bizard, a Swiss in the guards of Frontenac, was town-major of Montreal, 1674, and died there 1692. The island at the entrance to Back river was granted to him.

Philippe Carrion du Fresnay, of the Carignan regiment, established a trading post in Carillon island about 1665, and carried on illicit trade like Perrot. The name of the island has been corrupted into 'Carillon.'

Daniel Greysolon du Lhut, in 1689, defeated a party of Iroquois somewhere on Oka lake. Next year the Iroquois chief, Chaudière Noir, massacred a party of French traders near Carillon and kept the district in terror for five years. He was finally killed by a young Algonquin Indian.

About 1700 France inaugurated a new policy and forts were built along the St. Lawrence, which then became the military route, but fur traders still passed by the Ottawa river.

Their canoes, heavily laden with fur, had no choice but to creep along the north shore of Lake Superior to the Sault, avoiding the danger of gales by closely hugging the shores and cutting from headland to headland. Below the Sault, a fairly sheltered passage could be had between the Manitoulin islands and the north shore, leaving only about fifty miles of dangerous navigation to the mouth of the French river, whence the whole route was very much less exposed to wind than that by the St. Lawrence, although very many more portages had to be made.

This trade, however, only meant a journey up in the early Summer and a return during the Autumn, so that no settlement whatever was made along the route during the succeeding two hundred years. Even the commerce of the North-West Company, although great in itself and pregnant with romance, was selfish in its nature, and did not tend to civilize or develop the valley nor to open its broad fields to the benefit of humanity or turn its water powers to the manufacture of the world famous pine forests, that crested its shores.

Thus, at the close of the eighteenth century, Ste. Anne was the last church where the voyageur committed himself to God's care for the half year, that must elapse before he could return to the habitations of his fellow men.

PHILEMON WRIGHT'S SETTLEMENT.

It remained for a man from Massachusetts to break the spell of inactivity and win to Canada the lumber markets of the world.

Having made a reconnaissance in 1798 and '99, he boldly left his interests near Boston and, with five families and a score of able bodied workmen, accomplished the winter journey with sleighs to Montreal, where they arrived in February.

His name was Philemon Wright. Of Kentish stock, born at Woburn, Massachusetts, in the year of Wolfe's victory, he, in time became, like his father before him, a successful farmer and cattleman.

Land was rather scarce in Massachusetts, and the adherents of the old British regime had a none too enviable existence among the extremists of the late revolution. He was of Puritan descent and had learnt to do things, but the space and environment were not congenial to the attainment of his ambition. Thus we find him in mid-winter at Montreal, undaunted by snow and ice, but eager to take a trip far into the interior with men, who had never undertaken such an enterprise, and during the season, when even the hardy voyageur would never have attempted such a feat.

In a few days the caravan of horses, oxen and sleighs left Montreal, and in five days, arrived at the absolute western boundary of civilization, that is, at the head of

Oka lake. So far, the party had slept each night in farm houses. Now there was no road, no farm house, and the battle began with the forest primeval. A road had to be cut through the bush up to the present site of Hawkesbury, a distance of twelve miles—which occupied four days. At night the men slept beneath the blue canopy of heaven, well content to once more rest upon ground ruled by their beloved old Sovereign, George III.

At Hawkesbury the party took to the ice, which was covered by a foot of snow and this was their first experience of such travel. The men preceded the teams, testing with axes at every step. In this way, on the fifth day (7th March, 1800) they reached Hull, which had previously been chosen by Mr. Wright as the site of his future colony.

Without delay trees were cut down and camps built, and, so soon as the snow had gone, ground was put under cultivation. By the Autumn of the same year (1800) a mill had been built, and the good Massachusetts farmers were delighted at the abundant harvests yielded by the new land.

THE WRIGHT FARMS.

Farm after farm was brought under cultivation by Mr. Wright, and, in his evidence before a committee of the Quebec Legislature in 1823, the following list of his cultivated properties was presented.

'No. 1. 1800.—This farm was begun by P. Wright, junior, and is called the Grand or Ottawa river and was used as a farm for raising stock upon. Owing to the spring waters covering it about once every 7 years, sometimes we are obliged to put the stock and cattle on the high lands, as the waters remain about ten days upon this fine meadow. This farm is now managed by Sarah Wright.'

'No. 2, .1820.—This farm was begun by P. Wright, and is now superintended by T. Brigham, and is called the Waterloo farm; it is chiefly made use of as a meadow and hay farm, cleared land, about 120 acres.

'No. 3, 1810.—This farm was commenced by E. Chamberlin, and is called Chamberlin farm, and is now superintended by Asa Meech, and has about 200 acres of cleared land.

'No. 4, 1817.—This farm was commenced by John Rousenstrum, and is called Larnard farm, and is superintended by Larnard, has about 35 acres.

'No. 5, 1818.—This farm was commenced by Andrew Sandstrum, and is called the Swedish farm, and is superintended by T. Brigham, and is used as a grazing farm for the Columbia farm, and has about 15 acres cleared.

'No. 6, 1818.—This farm was commenced by David Benedict, and is called Benedict farm, is superintended by R. Wright, has about 30 acres under improvement and is used for grazing, pasture and mowing.

'No. 7, 1818.—This farm was commenced by Chase, and is called Richard's farm; is superintended by Richards, has about 80 acres of cleared land.

'No. 8, 1821.—This farm was commenced by P. Wright, jr., and is called the Chaudière Lake farm, and is superintended by Charles Sims (Aylmer), has a good house and store and lies upon the borders of the lake and is used as a public stand and tavern.

'No. 9, 1821.—This farm was commenced by G. Gilson, and is called the Gilson farm, and superintended by Gilson, and has about 15 acres cleared.

'No. 10, 1821.—This farm was commenced by John Underhand, and is called the Buckingham farm, and is superintended by Underhand, and has about 2 acres of cleared land.

'No. 11, 1821.—This farm was commenced by Wyer Levit, and is called Templeton farm, and is superintended by Levit, and has about 60 acres of cleared land.

'No. 12, 1821.—This farm was commenced by Vallie, and is called Vallie farm, and superintended by Vallie, and has about 40 acres cleared land.

'No. 13, 1822.—This farm was commenced by C. C. Wright, and is called the Gateno Height farm, and superintended by C. C. Wright, and has about 60 acres cut down and 30 under improvement.

'No. 14, 1822.—This farm was commenced by Abijah Lardord, and is called Lock Harbour farm, and is superintended by J. Foubert, and has about 12 acres cleared.

'No. 15, 1822.—This farm was commenced by Thomas Brigham, and is called Brigham farm, is also superintended by him, and has about 12 acres of cleared land.

STOCK AND EQUIPMENT.

Number.	Houses	Barns.	Stores.	Cleared acres of land.	Saw Mills.	Horses.	Oxen.	Cows.	Sheep.	Pigs.	Goats.	Tons of Hay.	Acres of Oats.	Acres of Wheat.	Acres of Potatoes.
1	2	1	0	350	0	5	4	12	12	20	0	130	15	25	20
2	1	1	0	120	0	2	2	3	0	2	0	60	0	4	20
3	2	1	0	200	0	3	2	9	0	6	0	110	12	15	15
4	1	1	0	35	0	0	0	2	0	2	0	20	2	6	6
5	1	0	0	15	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	30	1	0	0	0	0	0	0	5	0	0	0
7	1	1	0	80	0	1	4	3	0	7	0	50	8	15	20
8	1	1	2	30	0	2	2	2	0	4	0	0	0	4	0
9	1	1	0	15	0	0	2	5	0	3	0	15	2	3	3
10	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0
11	1	1	0	60	0	2	4	3	0	9	0	20	8	10	15
12	2	1	0	40	0	1	2	3	0	6	0	10	2	4	6
13	1	1	0	60	0	2	6	5	0	16	2	10	8	15	10
14	1	1	0	12	0	1	0	1	0	2	0	5	2	2	2
15	1	1	0	12	1	2	2	3	0	4	0	5	1	6	5

It is here reproduced as an astounding record of perseverance and well directed energy. In 1806, Mr. Wright took out his first raft of square timber, which he succeeded in conveying safely to Quebec. His proposition, to take cribs down the Long Sault and Carillon rapids, was regarded as impossible at the time, but nevertheless he accomplished the feat, arriving at Montreal island in twenty-eight days, whence he descended by the Back river, finding it preferable to the route by the St. Lawrence.

In May, 1808, after years of labour, a fire destroyed Mr. Wright's mill and buildings, but his raft was saved and the profit of its sale was utilized to build another mill in the autumn. In 1811 a thousand bushels of wheat were raised on the various farms, which were disposed of at $3 per bushel, owing to war prices.

In 1817 Mr. Wright was married by a notary at Grenville, the wedding party having proceeded down the river in four large bark canoes, but in 1819 he had built a steamboat, ninety-three feet keel, which plied between Hull and Grenville. He also stated (1823) that it was his intention soon to place a boat upon Aylmer lake.

STEAM NAVIGATION.

The matter of early steam navigation in Canada is very interesting, and it may not be out of place to here review it at some length. The first application of steam to the propulsion of a boat is a rather vexed question, and several rival claims are put forward for the honour. In 1773, Fitch, an American, propelled a steamer on the Delaware river by paddles, but the project was soon abandoned. Five years later, Patrick Miller, of Edinburgh, fashioned a steamboat, which went at the rate of five miles an hour, and in the following year, with Symington, built another steamboat, that attained a speed of seven miles an hour towing a load. Robert Fulton was an

American artist, who went to England inspired by the success of Benjamin West, He was introduced to the Duke of Bridgewater, and, under him became a canal engineer, and made many experiments with steamboats. In 1803 Fulton launched a boat upon the Seine, which, however, immediately sank with the weight of its machinery. In 1807 he, having studied the various experiments in Europe, built a steamer, with engines by Boulton and Watt. This made the voyage up the Hudson from New York to Albany, a distance of one hundred and fifty miles, at the rate of five miles an hour, which was regarded as an astounding feat.

Inspired by this, Mr. John Molson, of Montreal built a boat called the *Accommodation,* on the shore behind his brewery. She was launched sideways, and fitted with engines made by Boulton and Watt at the Soho Works. The *Accommodation* went from Montreal to Quebec in November, 1809, at the rate of four miles per hour. Between 1809 and 1812, Mr. Molson built the *Swiftsure, Malsham, Lady Sherbrooke* and *John Molson*, which steamers were engaged in the transportation of troops and supplies between Quebec and Montreal during the war of 1812.

The first ship actually to steam across the Atlantic without sails, was a Canadian—the *Royal William*—launched at Quebec, 1831, her engines coming from England. In 1833 she went from Pictou, N.S., to Gravesend, arriving September 11, after a twenty-two days' passage. This boat was built by Mr. John Molson, of Montreal. In 1834, she was sold to the Spanish government and named the *Isabel Segunda,* and was the first steamship to fire a shot in action.

DEVELOPMENT OF STEAM NAVIGATION BELOW OTTAWA.

The Ottawa, not only had the first steamboat west of Montreal, but maintained a steam navigation equal to the St. Lawrence till the 40's.

The Ottawa valley was opened to settlement about 1800. In 15 years a wooden lock was built at Vaudreuil, and Durham boats began ascending from Lachine to Point Fortune and St. Andrews. All goods, till 1825, were carted from Montreal to Lachine because there was a good road, and there the Durham boats were loaded for both the Ottawa and St. Lawrence routes. By the latter the boats proceeded, by the help of several small canals, to Kingston, but, by the former ,their usefulness ended at Point Fortune or St. Andrews. Above this, cartage was resorted to for 12 miles to the head of the rapids at Grenville, and then bark canoes to Hull, till Mr. Wright's steamboat in 1819 revolutionized the navigation of that stretch of river.

Mr. Wright's steamer the *Union* was built at Grenville in 1819. The motive power consisted of two heavy marine side lever engines, made by Messrs. Boulton & Watt at the Soho Works, Birmingham, and imported by Mr. John Molson of Montreal.

The timber commerce so increased the trade that the Durham boats were insufficient, and, in 1826, the first steamboat line was operated between Lachine and Carillon by Captain Johnson on the *William King,* and the next year Captain Lighthall brought out the *St. Andrew.* The latter had formerly been in charge of Judge McDonell's Durham boats that did all the business, freight and passage between Montreal, Point Fortune and St. Andrews.

In 1828, McPherson, Crane & Co., put the steamer *Shannon,* Captain Grant on this route. Meanwhile a great improvement was pending. The American War (1812-14) had emphasized the need of an interior route to Kingston, and, in 1827, the Imperial Government began the construction of the Carillon and the Grenville canals, and also the Rideau canal, Ottawa to Kingston. These were finished in 1833, and immediately we find the Ottawa and Rideau Forwarding Company established, with John Molson a director. He built the steamer *Ottawa,* Captain Lyman the *Shannon,* and other boats for the Montreal-Kingston trade. The journey was stage to Lachine and boat to Carillon 2 days; stage again to Grenville and boat to Bytown and Kingston 3 days, the freight being towed in barges.

The next year saw an experiment launched at Ottawa, the *Nonsuch,* a stern wheel boat, in which the old Boulton & Watt engine of the *Union* was placed. She ran for three seasons, but proved a failure.

In 1841, Captain Shepherd, the esteemed veteran boatman, accomplished several feats of river navigation. In July, he took the steamer *St. David* from Brockville through all the Cornwall and Coteau rapids to Lachine in one day, demonstrating the possibility of the now world renowned tourist route. Next day he went to St. Anne and made the first trip of a steamer with passengers on board up the Grenivlle canal. The same year he initiated the towing of rafts with steamboats, by taking one down Oka lake to the Lallemand rapid for Messrs. Hamilton & Low.

In September 1841, the Ottawa was so low that boats were unable to run the St. Anne rapid, and the first lock there was only being constructed. There was a lock at Vaudreuil, which, however, was owned by a private company that taxed all traffic except their own very heavily. At the request of other shippers, Captain Shepherd examined the rapids and found a channel outside the lock, through which he successfully piloted their barges. This broke the monopoly of the St. Andrews Trading Company at Vaudreuil, which they had enjoyed since 1816.

The completion of the St. Anne lock, autumn 1842, opened the first daily passenger route, without barges in tow, between Montreal and Ottawa. The steamer *Oldfield* was operated on the lower part, Montreal to Carillon, and the *Albion* on the upper portion, Grenville to Ottawa, with a stage line between Carillon and Grenville. The owners were Sir George Simpson, Governor of the Hudson's Bay Company, and Messrs. Momarquette, Gibb & Shepherd.

The route, however, faded into only local importance with the opening of the St. Lawrence canal system, 1846, and the old proprietors sold out to engage in the larger field of enterprise.

The existing railway was built in 1857 by Sykes and De Berg, and bought by the present navigation company in 1864. See page 516.

The towing business on the Ottawa received a great impetus about the fifties when the Chaudière water powers began to be developed and sawn lumber was shipped to Montreal and, via Whitehall, to New York.

Some of the best known steamers were the *Pioneer,* 1848, *Britannia,* 1852, *Queen Victoria,* 1865, burnt at Carillon, 1879, and the *Peerless.* Propellors began to be used after 1840.

The Montreal and Ottawa Forwarding Company was dissolved in 1884, and succeeded by two freight lines, the Ottawa Forwarding Company and one organized by Captain Hall, of L'Orignal. These amalgamated in 1890, and have now, several staunch propellors carrying local freight, salt, hay and farm products to and from the fifteen or twenty wharves between Ottawa and Montreal.

The lumber transport is done by powerful tug boats, towing four to six barges each, carrying from a quarter to a third of a million feet. The fleet of six tugs and eighty barges is owned and operated by Captain Denis Murphy, of Ottawa, who has been engaged in this business since 1856. The traffic amounts to about half a million tons per year, of which 80 per cent is lumber.

The passenger traffic is still carried on by the Ottawa River Navigation Company, founded in 1842. They operate a side wheel steamer, 5 ft. draft, between Ottawa and Grenville, and a similar one from Carillon to Montreal via St. Anne and the Lachine rapids.

It will be seen that the early canoe traffic continued for 200 years till the bateaux began to be used between Lachine and Point Fortune about 1810.

In 1819, Mr. Wright's steamboat, *Union,* between Hawkesbury and Hull initiated the steam era in the valley. In 1825, steamers were run between Lachine and Point Fortune, and 12 miles of rapids from Carillon to Hawkesbury constituted the only break between Lachine and Hull.

The opening of the Carillon, Chute-à-Blondeau and Grenville canals in 1833, made continuous navigation to Bytown and thence by the Rideau canal to Kingston. where the lake schooner took the business, the steamboats descending the St. Lawrence rapids to Montreal.

This circuitous system continued in vogue till 1846, when the 9 ft. draft canals down the St. Lawrence turned both the up and down traffic to that route.

DEVELOPMENT OF STEAM NAVIGATION ABOVE OTTAWA.

West of Ottawa, of course, the lumber trade required a navigation system. The first steamer on Deschenes lake was the *Lady Colborne,* Capt. Blackburn. Bouchette states, 1832, that it is 'hoped the benefits of steam navigation will soon be secured,' so the boat was probably launched, 1833. In 1846 the *Emerald* and *Oregon* (iron plate hulls) were built by Messrs. Egan and Aumond, thus inaugurating the Union Forwarding Company, whose steamers did all the transportation for the valley west of Ottawa during the next thirty years.

The first step in this route was the eight mile drive from Ottawa to Aylmer, long famous as the Holt stage line. There was a good macadam road, and freight was forwarded by large wagons carrying as much as five tons in one load. Supplies for the lumber camps, pork, beans, molasses, tea and axes, chain and rope were hauled daily all summer to the steamer wharf at Aylmer.

A side wheel steamboat left Aylmer each morning for the Chats falls, 25 miles up. Passengers were landed at a low level wharf in Pontiac bay, and elevated by a rising platform about 40 feet to the top of the rock cliff. They then embarked on a tram car drawn by two horses in tandem, and were carried three miles to the foot of Chats lake, where they boarded another steamboat that proceeded up the lake, and through the Chenaux current at low water to Portage du Fort. See page 529.

On Chats lake, the steamers *Oregon, Alliance* and *Prince Arthur,* all side-wheel boats of about 5 feet draft, did the freight and passenger business. During high water an auxilliary steamer was used between the head of Chenaux island and Portage du Fort, because the current was then so swift that passengers and freight had to be landed at the foot of the island.

The more usual route, however, was for the Chats lake steamer to land her passengers at Farrell bay below Chenaux current, whence they proceeded by stage to Cobden. Here a stern wheel steamer plied down Muskrat lake and river to Pembroke, following the ancient Indian trail over which Champlain passed in 1613. See pl. 9.

From Portage du Fort to Bryson, 12 miles, stages were again in requisition as the Grand Calumet falls and rapids below prevented navigation.

The steamer *Calumet* ran from Bryson up the north channel to Lapasse thence up Coulonge lake to Paquette rapids, which it was able to surmount and continue up the lake past Westmeath to the foot of Morrison island. Here the passengers walked up the length of the Allumette rapid and took a ferry to Pembroke, the capital of the upper Ottawa. During low water the steamer up Coulonge lake continued through the Culbute channel to Chapeau, where there was a stage line across the island and a ferry to Pembroke. The steamer *Calumet* was burnt and replaced by the *Sir John Young.*

This route from Bryson to Pembroke bid fair to become important and, after much agitation, combined locks, of wood, 200 feet long, 45 feet wide with 6 feet of water on the sills were built in 1877 to overcome the Culbute rapids. They were, probably, the largest wooden locks ever built, but were hardly used, as the railway was about that time extended to Pembroke and northwards, completely diverting the traffic.

Above Pembroke there was uninterrupted navigation for forty miles through the beautiful *Deep river* to Des Joachims rapids. The first passenger boat on this route

was the *Pontiac* in 1854, then followed the *Pembroke* 1860, the *John Egan* 1873, the *Christopher O'Kelly* the *Empress* and the *Ottawa*, 1882. At present the *Victoria*, 1896 gives a daily service.

Above Joachims, there was the steamer *Kipawa* to Rocher Capitaine and, between these rapids and those of Deux Rivieres, the steamer *Deux Rivieres*. The final stretch to Mattawa was made by the steamer *Mattawa*. But the glory departed from the route with the advent of the railway. First the passengers slackened, then the freight and then the rafts disappeared and the present boats are used for log towing alone.

ECONOMIC DEVELOPMENT OF THE VALLEY.

The following is a detailed account of the condition of the river at the present day, its wharves, bridges, canals and industries, together with brief historical notes regarding various points of interest. The extreme easterly end of the river may be considered as Bout de l'ile, or lower end of Montreal island. The landscape at this point reminds one of a Dutch sea-coast scene, and the alluvial flats won from the early voyageurs the name 'des Prairies', signifying meadows. See plate 4A.

A short distance from this easterly end of the river is the Great Northern railway bridge, which crosses from Bout de L'ile to Ile Bourdon, and thence to Charlemagne situated at the mouth of the Assomption river.

BACK RIVER.

Ile Bourdon derives its name from the Captain of the first sail boat that made its way up to Montreal. It was built at Quebec.

Two or three miles further up is the east end of Ile Jesus where the St. Eustache branch of Mille Iles river joins the main stream.

At mile 8 is Des Prairies village. Here the first indication of rock is seen, and the out-crop creates a rapid of about seven feet fall. Advantage of this was taken many years ago to build a small grist mill, which is still in use.

As we descend, the river banks become higher on both sides, but especially on the north, where they attain a height of seventy feet at the village of St. Vincent de Paul, and maintain that height up to Sault au Recollet.

There are several small islands below St. Vincent de Paul, also two large ones—Cheval de Terre, whose surface is as high as the north shore, and Ile Visitation, which stands at the foot of Recollect rapids.

These rapids extend up four miles to Bordeaux, and consist of a lower fall of twelve feet, a river slope of four feet and an upper fall of ten feet. Their name is derived from the drowning of a Recollet father. He was accompanied by an Indian boy called 'Ahuntsic,' after whom the summer resort at Pont Viau has been named.

Three bridges cross the river within three miles; Pont Viau, a highway bridge, by which a large amount of garden produce reaches Montreal; Bordeaux railway bridge, by which the Canadian Pacific railway leads out of the city to the north shore, and Cartierville bridge, a highway structure, by which St. Martin and St. Eustache farmers cross to the island of Montreal. At each of these three places a large number of persons spend the summer months, and there is an electric railway connection with the city.

For five miles above Cartierville the river has only a moderate current, expanding into almost a lake at Patton island. Above this the river narrows, and a swift current—the Whitehorse rapid—with a fall of four feet intervenes.

For two miles above to the foot of Ile Bizard the shores are about ten feet high, and the Bigras islands divide the river into several channels.

Ile Bizard stands in the entrance of Back river, dividing it into two channels. The northern one is practically a long bay extending down from Oka lake, which

ends in the Lallemand rapids about a mile long with a fall of eight feet. The south channel begins with a rapid, the Cap a l'Orme, falling three or four feet from Oka lake level, then a stretch of lake extending a mile below Ste. Genevieve and joining with the Lallemand rapids at the foot of the island by a one mile stretch of moderatte current. Ile Bizard derives its name from a French official, to whom it was granted. See plate 4A.

ST. EUSTACHE CHANNEL.

The most northerly branch of the Ottawa or Mille Iles river leaves Oka lake just near the head of the Lallemand rapids. The entry is a rapid of about five feet fall, at which the St. Eustache grist mill is located. Below, for fifteen miles to Terrebonne, is a pond dotted with numerous islands, from which it receives its name. The village of St. Eustache was the scene of fighting during 1837, and the church in which the defence was made is still pointed out to tourists. At Ste. Rose, seven miles below, the river is crossed by the Canadian Pacific railway on its way to Ste. Therese and Hull. Ten miles below Ste. Rose is Terrebonne with a good water power, which has made it a manufacturing centre. Five miles below this the Mille Iles river joins with the Back river again, at Lachenaie. See plate 3.

ST. EUSTACHE VILLAGE.

During the autumn of 1837, feeling ran high in the village and surrounding country. The news of the outbreak on the Richelieu arrived the 26th of November, and a band of extremists, four hundred strong, from the village and surrounding country marched to Oka and pillaged the government store, taking all guns and ammunition. They were unable to induce the chief of the Indians, however, to part with three small cannon that were in his care. A Swiss named Girod, plausible, pretentious and without truth, assumed the title of Commander-in-chief and inflamed the mob by his fiery eloquence and false representations.

On Sunday, December 10, the rioters, despite the appeals of the cure, occupied the church, to the exclusion of all other parishioners. They forcibly entered an unfinished building intended for a convent, and appropriated to themselves provisions from the priests' house.

On December 13, Sir John Colborne left Montreal with two thousand men and eight guns, arriving at St. Eustache the following morning. The main body crossed the ice four miles east of the village, covered by a small detachment that occupied the river bank opposite the town. Chenier, with one hundred and fifty men, attempted to cross the ice and oppose this detachment, but the cannon of the main body began firing and he was obliged to take refuge in the church. The troops then took up a position in the village and bombarded the church and convent for about an hour, when, through the overturning of a stove, the building took fire and the rioters surrendered. Chenier was shot through the head while endeavouring to escape. Girod fled before the arrival of the troops, and, hard pressed, committed suicide four days after at Pointe aux Trembles. As was then the custom, he was buried at the corner of two cross-roads, now St. Lawrence Main and Sherbrooke streets in the heart of Montreal city.

Seventy men lost their lives in this unfortunate affair. The column left the town at four o'clock in the afternoon and marched to St. Benoit. There they met Captain Mayne with his company of the 24th and eight companies of volunteers that he had marched from Carillon on December 12.

There was no further disturbance, and the troops returned to Montreal on December 15, but the village of St. Benoit was set on fire despite the efforts of the

troops to prevent further destruction. The 24th Regiment, it will be remembered, was cut to pieces in Zululand, 1878.

FORT SENNEVILLE.

The eastern end of Oka lake is blocked off from the St. Lawrence (Lake St. Louis) by the upper end of Montreal island and Ile Perrot. The upper end of Montreal island was granted to Du Gue of Bois Briant by the King of France in 1672, and in that year the first house was erected, Seven years later it was sold to Le Moyne and Le Ber, prominent fur traders of the time. Le Ber in 1688 erected a windmill, the ruins of which may still be seen. It was loop-holed for musketry defence against the Indians, but was captured two years after the massacre of Lachine, despite the gallant defence of Le Ber and his people.

This set-back was only temporary, however, and the indomitable Le Ber family erected a fort and a manor house near the site in 1693, the ruins of which are still pointed out as Fort Senneville. This was for one hundred years the most westerly mill and settlement of the colony.

Montreal was held during 1775-6 by Congress troops, and Cedars, 30 miles west, was occupied by them as an outpost.

AFFAIR AT CEDARS.

On May 12, 1776, Captain Forster left Oswegatchie, now Ogdensburg, with thirty-six men of the 8th Regiment, and proceeded down the St. Lawrence to Cedars, gathering on the way some two hundred Indians.

Captain Butterfield, who was in command at Cedars, surrendered May 19, with three hundred Congress troops. The day after, Sherburn's force of one hundred Congress troops, marching to relieve Butterfield, was captured by Forster, who then advanced to Vaudreuil village. On May 23, two hundred and fifty of his prisoners were placed at Fort Senneville, the remainder being left at Vaudreuil, while the American officers were sent to the Indian mission at Oka.

On May 24, Forster advanced towards Lachine, but found General Arnold entrenched there with two thousand men, so he was obliged to fall back to Vaudreuil.

Arnold advanced to Senneville and burnt the fort, but the prisoners had been removed by DeMontigny to Ile aux Tourtes. Forster's force fired upon Arnold's scows and obliged him to retire. During the next day a cartel for exchange of prisoners was sent to Arnold, and the congress troops were liberated on the 30th of May; Arnold having the 28th returned to Montreal, while Forster went back to Oswegatchie.

Owing to the falsity of Arnold's report of the affair and the animus of congress, the exchange of prisoners was repudiated and a corresponding number of British prisoners was never released.

STE. ANNE, VAUDREUIL AND OKA.

Ile Perrot was granted to a fur trader of that name about the year 1670 (the date of the incorporation of the Hudson Bay Company) and it had its windmill and trading post. It will be remarked that no development of water power was undertaken, the windmill being more cheap and simple and of sufficient capacity for the requirements of that day.

Across the rapids, that divide Ile Perrott from Montreal island, is the pretty town of Ste. Anne. A church was erected here in 1703, at which the voyageurs placed themselves under the protection of their tutelar 'Saint Anne' ere they set out on their 400-mile canoe trip to Georgian bay. Here the season's voyage was considered to begin, and the weather-beaten canoemen first welcomed home and friends on their

return in the autumn. This fact so imbued the immortal Moore that he was inspired to write his Canadian boat song:—

"Row brothers, row, the stream runs fast,
"The rapids are near, and the daylight is past."

At the west end of Ile Perrot is another rapid, separating it from the mainland and the village of Dorion or Vaudreuil station. This was the headquarters of the St. Andrew's Trading Company, and a stone building bearing the date 1797, is still in existence. A wooden lock was built to overcome these rapids in 1816. Here again the ruins of an old windmill are to be seen.

Six miles above Montreal island the lake is narrowed in by Oka Point from the north. This is a mountain corresponding with that at Montreal. It is remarkable that all these mountains, Rigaud, Oka, Montreal and St. Hilaire, are nearly in the same straight line. Oka was an Indian settlement established in 1721, when the tribe was transferred from Sault au Recollet. Four chapels were built upon the mountain in rear about 1740.

Four miles east of the village is a Trappist monastery and farm established in 1892. Across the lake are the villages of Hudson and Como.

Near the upper end of Oka lake is Carillon island, about five miles below the town of that name. The island and point just above it are practically a presque'ile, formed by the silt from the North river, which flows in at this place.

ST. ANDREWS.

St. Andrews may certainly lay claim to being the earliest and most thriving town of the Ottawa Valley, although now rarely heard of, as it gradually gave way to Lachute, the village it contributed to build up in the early days. It is situated two miles up the North river at a small fall, that furnished power for its industries and barred further navigation up stream.

In 1810, one Davies, from New Hampshire, opened a store at St. Andrews. He seems to have been an old time surveyor, and to have made a plot of the town site in 1799. He opened a tannery, harness shop, saw mill, grist mill and ashery, and a paper mill—the first in Canada—which was sold in 1810 to a Scotchman named Brown. In 1816 Davis built a lock at Vaudreuil for the St. Andrews Trading Company, which gave them a hold upon the trade of the valley for many years.

During the early days there was a stage line from Montreal to St. Eustache, and up to St. Andrews and Grenville. The trip took 3 days, or two trips per week, and the stage driver's hat was the post office of the valley. In 1826, when steamboats appeared, the stages were placed between Carillon and Grenville, in competition with the south shore stage line from Point Fortune to Chute à Blondeau and Hawkesbury.

St. Andrews was the distributing port for the territory now included in the counties of Argenteuil and Two Mountains. In 1814 the following prices ruled for provisions: Corn, \$2; rye, \$2.50; and salt, 2.40 per bushel; sugar, 40 cents and tea, \$1.80 per pound; coloured cotton, 60 cents, and cambric, 74 cents per yard.

South of this is the town of Rigaud on a small river of the same name. About a mile up from the mouth is a dam and mill. In rear of the village is Rigaud mountain, upon the summit of which is the so-called 'Devil's Garden,' an aggregation of rounded stones the remains of a glacial moraine.

CARILLON.

The lake ends at Carillon rapids, 50 miles from Montreal. There are two towns. Point Fortune to the south and Carillon on the north. Carillon is likely named after Philippe Carrion.

The land here was granted by the Seignior before 1800, but Captain Schagel was the first to build a house (1804). The settlement was of small importance till the military canal was begun, 1827, when it at once became the headquarters of officialdom.

Commissary General Forbes was its leading figure and motive force. He was born in 1786, and fought as a young ensign at Waterloo. When ordered to the Montreal command, he became attracted by the exquisite charm of the view from Carillon hill, so built a residence —'Bellevue'—in 1827, where he entertained lavishly the different governors and distinguished civil and military personages. The residence still exists, and also a stone hotel built by him and occupied by the Royal Staff Corps during the canal construction, but a mill, a brewery and other ventures proved failures and have gone to decay.

During 1837 Forbes acted as military adviser to Sir John Colborne. Strangely enough, a Swiss, the tutor to the Forbes family, was Girod, who incited the habitants of the district to riot, but deserted them when conflict became imminent. He boasted that he and his 'staff' would eat their Christmas dinner at 'Bellevue,' and wash it down with the commissary's wine.

The citizens of Carillon and the neighbourhood organized eight companies of militia under Captain Myers of the 24th regiment and occupied St. Benoit in December, 1837.

The commissary was also a magistrate and tried local cases, so that the Bellevue cellars frequently held rowdy shanty-men as well as sherry.

When canal construction was completed in 1834, Carillon of course diminished in size, but still had the increased boating business. This, however, disappeared on the completion of the St. Lawrence canals, (1846) never to return, but a revival of trade set in with the development of the lumber industry at Ottawa in 1860, and, twelve years afterwards, the canal was enlarged and the Carillon dam completed.

CHUTE-Â-BLONDEAU.

Before the Carillon dam was built, a rapid existed between the Carillon and Grenville canals, which was overcome by a short canal and lock along the Quebec shore. This rapid is extinguished now by the dam, but on the south shore opposite Greece Point is a sawmill and the old village of Chute-â-Blondeau on top of the steep bank. The pioneer was Wyman, who came from Massachusetts in 1804 and erected a grist mill. It was a stopping place for the men engaged in working the square timber rafts through the Long Sault rapids, and Kirby's hotel was a well known hostelry in the old days.

Rafts usually consisted then of 72 cribs. They were anchored at Grenville, the head of the Long Sault, and were divided into 'bands' of six cribs for running the rapids. It required one pilot and thirteen men for each band, and this crew made three trips a day from Hawkesbury to Point Fortune. A number of jobbers or extra hands squatted in the vicinity of Chute à Blondeau, and when the raft running was over, they lived the rest of the season as best they could, without farms or regular employment. The settlement became notorious for thieving and lawlessness, and at one time the Chatham farmers organized a raid upon the squatters to punish their misdoings.

Near Chute-â-Blondeau is supposed to be the site of the defence of Dollard and sixteen associates against a party of 300 Indians in 1660. The Indians seem to have made the locality a favourite resort and camping ground. Many relics and bones have been found about the farm and quarry of Mr. Ross, who settled here in 1840.

In 1857 a railway was constructed between Carillon and Grenville as the commencement of a line between Bytown and Montreal. Work was commenced also at

Montreal and St. Eustache and St. Andrews on an extravagant scale. A steam mill was built at the latter place to saw lumber, wells being bored to supply water for the boilers. Construction proceeded for two years, the financing being done by the firm of Sikes & De Berg, but the latter gentleman was accidently drowned, and it was found impracticable to proceed. Carillon to Grenville was the only portion completed, and serves to transfer passengers and avoid the loss of time in passing the canals. It was, therefore, bought by the Navigation Company in 1863. It is the only broad gauge railway in America, being 5 ft. 6 in.

MILITARY CANALS, CARILLON TO GRENVILLE.

Carillon was a military post during the construction of the canal there by the Royal Staff Corps, in 1827.

Regarding this canal I quote from Mr. T. C. Keefer's Canals of Canada, 1894, page 17: 'The St. Lawrence route was by the Royal Engineers considered to be 'too near the frontier for a military one. The influence of the Imperial gov- 'ernment was exercisd in favour of an interior route between Montreal and King- 'ston, via the Ottawa and Rideau rivers. The Government of Upper Canada was 'offered financial aid in 1824 to undertake the Rideau canal, but declined upon the 'ground that the St. Lawrence would best serve the interests of the country. The 'British government decided in 1826, however, to carry out the inland communica- 'tion which had been commenced upon the Ottawa at Grenville in 1819.'

The Imperial government operated these canals till 1856, when they were handed over to the provincial authorities. The 9-foot St. Lawrence canals, completed 1845, rendered the Rideau and Ottawa system commercially of little importance. All the canal records were burnt in the ordnance office, Montreal, during the riots of 1849.

The Carillon canal originally ascended 21 feet of a rocky bluff by two combined locks at the foot, the walls of which were formed by the rock cutting itself. It then descended 13 feet back into the Ottawa. The summit was supplied by a feeder from the North river. This canal may be traced upon the ground at the present day, and the two locks at Carillon and that at the upper end are in good enough condition to show all the details of construction. The length of the canal was 2·9 miles. A defensible house of stone is yet to be seen at the upper lock. The weir for feeding the summit from the North river can yet be traced, but is much fallen to decay. The locks were 106½ feet long, 19½ feet wide, with 6 feet of water on the sills.

About 3½ miles above the Carillon canal was the Chute-â-Blondeau rapid, named after a resident drowned there in the early days, but anglicized into 'Shoot-a-Blunder.' To overcome this a lock of 3·6 feet lift, with a short canal, was constructed along the main shore. The lock wall consisted of the natural rock, upon which a masonry wall was built, as the rock surface was not high enough. The lock gates are in place and the construction can be clearly traced.

The proposal to use the natural rock as part of the sides of the lock chamber in the present project, is only a return to the practice of 1828.

One mile above the Chute-a-Blondeau was the lower entrance to the Grenville canal, which surmounted the Long Sault. The length of canal was 5¾ miles, with seven locks rising 45 feet. The three lower locks were first constructed of the same dimensions as the old Carillon canal below, that is, 106½ feet to 108½ feet long by 19¼ feet wide, capable of passing vessels 96 feet long, 19 feet beam and 4½ feet draft. The four upper locks were, however, 129½ feet to 131½ feet long by 32¼ feet wide.

There seems to have been a great variation of ideas as to the proper length and width of the early locks in Canada. In this connection I append a table from Mr. T. C. Keefer's Canals of Canada, 1894.

DATES AND DIMENSIONS, CANADIAN LOCKS.

Year.	——	Length.	Width.	Depth.
		Ft.	Ft.	Ft.
1798	Sault Ste. Marie	38	8¾	2 on sill
1780	Locks at Cascades and Coteau	35	6	2½ "
1804	Locks at Cascades ad Coteau	110	20	4 "
1819	Military canals, Ottawa River (Grenville)	106½	19¼	6½ "
1825	Lachine Canal	100	24	4½
1829	First Welland Canal (wooden locks)	110	22	8 "
1832	Ride au Canal	134	33	5 "
1834	Grenville Canal (Ottawa River)	130¾	32⅛	6½ "
1834	Carillon Canal (Ottawa River)	126½	32	6 "
1834	Chute-a-Blondeau (Ottawa River)	131	33	6 "
1843	Ste. Anne Lock (Ottawa River)	190	45	6 "
1843	Chambly Canal (Richelieu River)	118	23	7 "
1843	Cornwall Canal (St. Lawrence River)	200	55	9 "
1846	Beauharnois Canal (St. Lawrence River)	200	45	9 "
1846	Second Welland Canal	150	26½	10½ "
1847	St. Ours Lock (Richelieu River)	200	45	7 "
1880	Culbute (Ottawa River) wooden lock	200	45	5 "
1890	St. Lawrence and Welland	270	45	14 "
1890	Grenville (Carillon and Ste. Anne)	200	45	9 "
1892	Sault Ste. Marie	900	60	19 "

The Trent canal locks were of similar dimensions to those of the Rideau.

It appears that seven locks were constructed between 1819 and 1826, that is the three locks of the old Carillon, the Chute-a-Blondeau lock and the three lower locks of the Grenville Canal, of a length of 106 feet and width of 19½ feet, with 6 feet of water, but the remaining four locks on the upper end of the Grenville were made 129 by 32 feet, with 6 feet depth. The Carillon locks and the Chute-a-Blondeau locks seem to have been enlarged to 129 feet by 32, but the three lower locks of the Grenville canal were still only 106 by 19 and limited the size of vessel until 1865 at any rate.

The St. Anne rapids were not included in the military scheme. There is only about 3 feet fall, and probably boats were towed up or passed by the wooden lock at Vaudreuil. As the Lachine locks were only 100 x 24 x 4½ compared with 134 x 33 x 5 for the Rideau, it is possible that the intention was to have the military system of canals extend down the Back river instead of via St. Anne. The Grenville locks were commenced before the Lachine.

The St. Anne lock was begun in 1839 and completed June, 1843. It was 190 feet x 45, with 6 feet depth.

The Lachine canal was first proposed in 1791, but, as the wagon road was excellent from Montreal to Lachine, only seven miles, no canal was undertaken and Lachine was made the starting point. This is why the canals and locks at Cascades and Coteau were constructed before the Lachine. The Lachine was built between 1821 and 1824, with seven locks 100 feet long, 20 or 24 feet wide and 5 feet depth.

ENLARGEMENT OF OTTAWA CANALS.

The navigation between Carillon and Grenville was enlarged, in 1871 at Grenville and 1873 at Carillon. Carillon was completed in 1882 and Grenville in 1887. The traffic on the military canals between 1858 and 1867 had doubled, due to the rapid development of lumbering at Ottawa. A dam was built across the Ottawa river at Carillon, raising the water 9 feet and obliterating Chute-a-Blondeau rapid. The old summit canal at Carillon was abandoned, and a new one, three-quarters of a mile long, with two locks, constructed along the north shore.

The river stretch to Greece Point, at the foot of the present Carillon canal, is nearly six miles. The Grenville canal enlargement followed closely the old military

canal, and the locks were used as weirs for the new canal. There are three locks in the lower mile and a half, then a three mile reach and two locks in the upper mile and a half,—total lockage, 45 feet. All the locks are now 200 feet x 45 x 9 feet of water, the scale fixed for the Ottawa and Lake Champlain route, but the Chambly canal has never been deepened, nor has the New York State canal between Lake Champlain and the Hudson river.

CARILLON DAM.

The plans adopted for the Carillon dam, after the survey of Mr. Bell in 1879, were similar to those proposed by Mr. Clark in 1860, but the locks were built on the north side instead of Clark's location on the south. The outside bank of the Carillon canal is of clay and rock, protected on the river side by cribwork, this toe crib in turn being protected with rip rap. On the canal side is a cement rubble wall, with 3 feet of pud dle behind it.

The dam is an arc about 1,700 feet long, with a double timber slide near the south shore; originally the river was divided into three channels by reefs of rock, the south channel 100 feet wide, the centre 400 and the north 100 feet, the bottom being covered with gravel and boulders.

At the end of three years, only the crib foundations of the dam in the shallow parts had been completed, a length of 1,500 feet. A new contract was let in 1879 and the plan modified to detached piers with gates between. In 1881 the old military canal was closed and the new one opened to traffic, but in 1883 the current had undermined the shale rock beneath the cribwork, and practically a reconstruction had to be undertaken. A crib was sunk 1,000 feet above the break, and from it other cribs were let down by cables until a ring dam was formed above the gap. The deep hole scoured out in the rock was filled with cribwork of a very solid kind; the other portions of the dam were repaired and the whole work completed in the autumn of 1884.

The depth of water flowing over the dam varies from a foot at low stages to 10 or 14 feet at high.

The dam is equipped with a timber slide, and, being the last on the route, its records indicate the growth and decline of the square timber business. In 1882 there were 73 rafts of 50 cribs, or 3,650 cribs passed; in 1895 only 6 rafts of 200 cribs, or 1,200 cribs. In 1870 there were about 1,400 cribs of timber. Of late years practically no square timber has been taken down, as detailed orders for dimension timber and plank are sent from the British and other markets.

POINT FORTUNE.

Point Fortune was for thirty years after 1800 the Castle Garden of the Ottawa valley. All the settlers passed by there till the canal was constructed in 1833 on the north shore, giving Carillon the pre-eminence.

Colonel William Fortune received a grant of 1,000 acres on the Ottawa in 1788. He was an old time surveyor and the village was named after him, but there was another Fortune—a bad Fortune, who, as is ever the case, constantly became mixed with the good Fortune. At L'Orignal he is reputed to have had a hotel, but got into difficulties and was obliged to remove. The village was situated just on the boundary line between Ontario and Quebec, so sagaciously enough, he built a house straddling the line, and then defied the excise officers of both provinces.

After 1763, several individual fur traders trafficed in the Ottawa valley and northward, encroaching upon the territory of the Hudson's Bay Company (founded 1670). About 1784 these traders combined to form the Northwest Fur Company, with headquarters at 'Beaver Hall,' Montreal. Brigades of this company's canoes left Lachine each spring and Point Fortune, 40 miles west, and just at the foot of the first for-

midable rapid was the natural stopping place, St. Anne being but a current in comparison. In busy seasons thirty canoes, each with eight to twelve men, laid up for the night at the village to gum the joints of the birch bark and prepare for the arduous work of the morrow.

In 1810, J. J. Astor of New York started a canoe line up the Ottawa to the northwest states. One or two large canoes carrying four tons did go through, but the war of 1812 stopped the scheme.

Colonel John Macdonell, who was an old 'Norwester' settled at Point Fortune in 1813, and four years later built a stone house which remains to the present. There were then but six permanent habitations, but soon this energetic gentleman built a grist mill and embarked in other ventures—storekeeping, potash making, lumbering and farming. Thus does one orderly and disciplined mind found a settlement, where for 200 years, there was nothing more abiding than the tent of the nomadic voyageur.

It is stated that Colonel Macdonell built a short canal, with a lock to pass boats up the worst part of the rapids above the village. No trace of this is to be seen today, but possibly the Carillon dam effaced it.

Miles Macdonell, a younger brother of the Colonel, and of Bishop Macdonell of Glengarry, was one of the romantic and devoted young man who attached themselves to the Selkirk schemes.

The Carillon canal, opened in 1833, allowed business to pass up without paying tribute to either town, but still a stage line for passenger traffic continued on both sides of the river till the opening of the St. Lawrence canals in 1846. Steamboats hitherto had been obliged to ascend by the Ottawa and Rideau route to Kingston, their return trip, however, was by the St. Lawrence, running all the rapids to Montreal.

There is a ferry service between Point Fortune and Carillon. It was begun by Schagel of Carillon, probably about 1827 when the canal was commencing. Some years later a horse-power boat was put on by Monmarquette, and operated by Kelly for 15 years, when it was sold to Poitras who placed a steamboat in the service.

A railway from Rigaud to Point Fortune was built in 1892, and is now a branch from the Canadian Pacific main line. This has improved conditions, and the isolated village now shares in the suburban trade of Montreal.

GREECE POINT AND STONEFIELD.

Greece Point, the foot of the Grenville canal, is located on a grant given Brig.-General Allan McNab of the 84th Regiment, the location ticket being dated 31st December, 1788. The grant was 5,000 acres in Chatham, county of York, as the district was then called. It was sold to Major Lachlan McLean, 60th Regiment, in 1790, and by him to John William Greece for $3,000. Parts have been sold outright, but about 1,000 acres are leased to various parties, who farm or are employed upon the barges or steamboats.

Stonefield, halfway between Greece Point and Grenville, is most appropriataely named, boulders being strewn about in all directions, the moraine of an ancient glacier. It is remarkable that people settled on these forbidding lands at a date when splendid areas could be had for the asking. Even yet it is hardly realized that stoney soil will produce a more valuable crop of trees than anything else, and by leaving occasional seed trees the supply will maintain itself.

The early settlers, however, depended on the ready cash from potash, which was a brisk trade till 1830. Sixty large maple trees were felled, cut up and burnt to supply the ashes for one barrel of boiled down lye, which weighed 650 or 700 pounds, worth about $8.50. As the hardwood disappeared, the potash makers went elsewhere; being perforce good axemen, they sought employment with the lumbering firms.

In the lumber shanties they found social enjoyment among their co-workers, and the dangers and excitement of the river driving in the spring conduced to form a

wild, roving and romantic strain that still declares itself in the district. They were brave, generous and proud as Lucifer of their individual prowess in axemanship, woodcraft and river driving. They formed a democracy as perfect as that among school boys. The final resort was fisticuffs and rough and tumble, but never the cowardly firearm of the west and south. Unfortunately, mature years did not bring affluence, ease and mental attainments, so a great Spartan force was lost to Canada.

The stirring lumbering work made farming appear drudgery and humdrum. His farm was but a *pied-a-terre.* His wife and children sowed the crop, and his home coming was harvest time, but, as youth and strength waned, the farm was seen to be the mainstay. Unfortunately, it often proved to have been badly located and poorly tilled, at a time, too, when declining health and lack of knowledge made it impossible to correct the mistake.

GRENVILLE VILLAGE.

Grenville was a military village at the time of the canal construction. Its position at the head of an impassable barrier in a great stream, gave it importance as a transfer point, but with the completion of the canals, it ceased to levy toll upon commerce.

In 1802, Archie McMillan, from Lochaber, Inverness, received grants of land in the townships of Grenville, Templeton and Lochaber, the latter named from his native town. He brought out many Highland settlers, and the surveys of the lands and their erection into townships took place between 1803 and 1808.

In 1810, McMillan built himself a large log house called the 'Old Abbey,' and began to reside at Grenville. His nearest neighbours were in Chatham township to the east, and the newly formed Wright settlement at Hull to the west; in fact there was Hull alone between him and China. The only road eastward to St. Andrews and civilization was a footpath along the river fit for sleds in winter; westward there was not even a footpath. Carts hauled freight from Montreal to Lachine, bateaux were rowed or poled up the rapids to Carillon, and then hauled along shore by men and ropes to Grenville. Nevertheless, McMillan and his Highlanders formed a militia battalion for service in 1812-14, but arrived at Pointe Claire too late for the fight at Chateauguay.

He was the first postmaster 1819-28, when the mail to Hull was carried by canoe or on foot for $8 per trip. The Quebec government granted $25,000 for a road to Hull, and it was let in two contracts. Papineau built the upper portion and Kains the lower, completing the work in 1830. There were then two steamboats plying to Hull; the canals were in course of construction at both Grenville and Bytown, and the first suspension bridge was about finished at the Chaudiere.

Business was brisk about 1820, due to the rafts, which began to descend in numbers every spring, Captain Pridham's being the stopping place for many river men.

About two miles above Grenville is Calumet, the railway station half way between Montreal and Hull, where the North Shore line Canadian Pacific Railway first comes in sight of the river. This railway was built by the Quebec government (1875), as the Quebec, Montreal, Ottawa & Occidental railway, and taken over five years after, as far as Montreal, by the Canadian Pacific. It passes through Lachute, Calumet, Papineauville and Buckingham, always within a mile of the shore.

THE ROUGE RIVER.

At Calumet a steep rock spur of the Laurentians, in which a graphite mine is located, gives the town the appearance of a Rocky Mountain mining camp. Above Calumet the Rouge flows into the Ottawa with a rapid of great beauty. The falls on the Rouge are now utilized for water-power. They have a romantic history, as legend states that they were a place of Indian sacrifice and so-called 'Manitou.' Toward the close of the seventeenth century the Iroquois made a raid upon the rench

settlementment near Ste. Anne. The marauders retired to the Rouge to hold a war feast, but were pursued and routed by a French punitive force. The Iroquois chief, in attempting to escape up river, was drowned, or fell into a deep fissue in the table rock near Iroquois chute.

This river, 90 miles long, drains a basin of 180 sq. miles, in which are numerous lakes. Nomining, 15 sq. miles; Tremblant, 6 sq. miles, &c., has a tributary—the Maskinonge—30 miles long, that drains lake Labelle, 5 sq. miles and Cameron, 3 sq. miles. The first timber taken off its basin was in 1804 for the Hawkesbury mills. The year previous a whole gang was drowned in attempting to drive logs. The Hon. J. K. Ward, owned large limits on the Rouge about 1870. See plate 3.

HAWKESBURY.

At the head of the Long Sault rapids on the south or Ontario side of the river and opposite the village of Grenville, is Hawkesbury, the largest town between Montreal and Ottawa, and situated just half way from each. Colonel Cole of Vermont settled on lot 2, first concession, East Hawkesbury, in 1790, but moved to Chatham in 1805.

Judge Johnston, who was the first magistrate of the Ottawa district, settled at Hawkesbury, 1796, and his son, the first child born there, was Captain of the 'Union,' 1819, the first steamer between Grenville and Bytown.

Dr. David Pattee and Thomas Mears were the founders of the milling business, in 1805, that endures to the present day. Mears was also the builder of a paper mill —the first in Canada—previous to this, and his was the first store. He also built the steamer *Union*, 1819, referred to above, and another boat in 1823. Stevens, whose name was given to the island below Hawkesbury, was a millwright with Mears, as were also the Herseys from Massachusetts. Dr. Pattee was the first doctor in Longueuil.

The mills were sold in 1808 to the Hamilton brothers, who had come from Ireland to Quebec and begun shipping lumber to Liverpool and building ships. A remarkable series of misfortunes befell the Hamiltons in 1822. Both the brother in Quebec and the one in Liverpool, who was financial agent for the company, died, and the residence of the third brother at Hawkesbury was burned. The finances of the undertaking were thus so upset that the surviving brother was obliged to visit England. On the journey down river, his canoe was upset in the St. Anne rapids and three children drowned. Before Mr. Hamilton's death, however, in 1839, he had amassed a large fortune. Colonel McMillan, the founder of Grenville. before referred to, and Mr. George Hamilton, known as 'Judge,' were intimate friends, and notified one another when entertaining acquaintances, by hoisting flags on either side of the river. Colonel McMillan died of cholera in 1832.

In the country about Hawkesbury, many pensioners of the war, 1812-14 were settled, and lived to ripe old age, five dying between ninety and one hundred. Cobbs island, in front of the town, received its name from the village blacksmith, and some veritable wag christened the adjoining island 'Cobbstail.'

The Hawkesbury mills were a great factor in the development of the valley; the money dispersed for wages on the Rouge, the Gatineau and up as far as the Dumoine, gave great assistance to settlers in their first starts.

The Canada Atlantic, now Grand Trunk railway, built a branch into the town about 1896, and the Great Northern bridge was completed about the year 1900, giving access by that road to Quebec. There is a span of 114 feet over the Grenville canal, with flanking spans of 55 feet each; then a wooden trestle, 315 feet long, leads to the shore, whence the main bridge of seven spans, each 206½ feet, extends across the Ottawa to Hawkesbury. The piers were built in the rapid water, and considerable difficulty was experienced in removing the boulders, gravel and sawdust

which overlaid the rock in some cases. The Ontario end of the bridge is a timber trestle, 1,320 feet in length, which crosses the main street of Hawkesbury.

Lumber may be shipped from Hawkesbury by rail or by barge to Montreal or to Lake Champlain, and coal for the Riordan pulp mills is brought in by boat.

L'ORIGNAL.

Five miles above Hawkesbury is L'Orignal (the moose), the county town of Prescott. There is a saw mill here, and between it and Hawkesbury are two other mills along the shore. The river here expands into a lake for five miles, the south part being a shallow bay, that necessitates a long approach to the town wharf.

The township of Longueuil was granted as a seignoiry to Baron de Longueuil 1672, being the only one ever granted in the area of the present Province of Ontario. It was sold to N. H. Treadwell, 1796, for £1,000, but he would not take the oath of allegiance during the war of 1812-14, and, like other Americans, was obliged to leave the district. His son, however, C. P. Treadwell, recovered his father's land in L'Orignal, 1823. A homage title was granted, 1827, and he became sheriff of Prescott, and Russell, 1834. He was an active citizen, and advocated a Pacific railroad in 1845.

The first child born in L'Orignal was John Wurtele Marston, 1806. His father came from New Hampshire, and visited L'Orignal with Mr. Treadwell in 1796, settling there 3 years later.

Hon. Alex. Grant, born 1773, was a Nor'wester, but in 1805 bought L'Orignal Point and began trading with the Indians on his own account. He discovered Caledonia Springs, 1806. L'Orignal was called then 'New Longueuil,' and consisted of but a few houses, in fact there were only a few settlers in the county.

Captain Pridham came to Montreal, 1815, and lived in Lachine, leaving there November, 1820, for L'Orignal, to build a house for Mr. Grant. He made the journey to Point Fortune with his wife by bateau; leaving November 12, they spent the first night at Pointe Claire, the next at Ste. Anne, the next at Como, and finally at Point Fortune, whence the last stage was made afoot. In June, 1821, Pridham walked to Montreal and back; such was early travel along the river.

L'Orignal became the county seat only in 1825, and then it was but a hamlet of twelve houses. The courthouse was begun the same year, and, in 1828, a delinquent was condemned to the pillory, which stood in front of the courthouse. Among old documents the lash for stealing is recorded 1817, and up to the good full measure of thirty-nine.

Saw-milling and grist-milling were carried on, and later a tannery and a marble cutting shop were erected, the latter still being in existence.

Above L'Orignal lake both sides of the river are steep, but of only medium height up to Montebello.

MONTEBELLO AND PAPINEAUVILLE.

In front of the town is Ile Rosalie, a point of the Laurentian granite that crosses the river just here and gives to it the familiar scenery of the Thousand Islands. Champlain exchanged one of his crew for an Indian here as hostage. At one time, possibly the river had another bed south of this point, along the line of the Georgian lake and other ponds to an outlet in L'Orignal bay. See plate 6.

Dr. Ebenezer Winters, an American, who had fought at Bunker Hill, settled at Montebello between 1815-20, and practised medicine.

Montebello was the home of Hon. L. J. Papineau, a leading agitator in 1837; after pardon was extended to all participants, he returned to live here in retirement and greatly beautified the place. The seigniory was granted to Bishop Laval in 1674, who

was, therefore, the first to hold land in the valley, just four years after the Hudson Bay Company received its charter in America. Papineau obtained the seigniory by purchase. It was about 15 miles square, and included the lower part of the North Nation river basin from Simon lake, and all of the Salmon river basin with its head lake, Papineau. About 1890, Senator Owens purchased 128 square miles of it, and now there is a thriving lumber business at the new town of Fawcett at the mouth of the Salmon river.

Papineauville is 4 miles further up, but cannot be seen from the river, owing to a long point of land extending from the mouth of the North Nation river and enclosing a narrow bay in front of the village. There is a steamer wharf on the river side of the point, whence freight and passengers are transferred to the bay and then scowed to the village. The saw-mills of Senator Owens has also a wharf for loading lumber barges.

On the Ontario shore, although steep and fairly high to the mouth of the South Nation, there are several wharves where the navigation companies land the freight for inland towns; thus Brown's wharf, Lefaivre and Treadwell give access to Alfred Centre in Alfred township and Jessup Falls in Plantagenet township.

SOUTH NATION RIVER.

The South Nation river drains a basin of 1,400 square miles, stretching back to within 3 miles of the St. Lawrence at Iroquois and Prescott. It was a great factor in the settlement of the townships of Plantagenet, Clarence, Cumberland and Gloucester, fronting upon the Ottawa river. Down its valley and along its tributaries, the Castor, the Scotch river and the Brook, came the lumberman in search of pine as early as 1810. The logs could easily be brought down to the 'Pitchoff' or Jessup Falls, and here a sawmill business soon developed. See plate 3.

Colonel Fortune secured land here 1811, and with Mr. Hagar, built a dam and operated mills, 1812. Plantagenet Springs were discovered 1800, but were little known till the beneficial effects of the water during the cholera, 1832, brought them into notice.

As settlement proceeded, the river was the highway and lumber was loaded on canoes at the falls and taken up to Casselman; in later years, a tug and scow were in the service.

Prescott county was generally settled by the same class of people as Argenteuil county across the Ottawa, but the ready communication with the St. Lawrence front by the Nation river brought in a number of United Empire loyalists.

In 1816, the Ottawa district was formed out of portions of the present counties of Prescott, Russell and Carleton; till then Prescott formed a part of Glengarry.

Just about the mouth of the South Nation is the village of Wendover, and a wharf serving the township of Plantagenet. Across the river on the north shore is another long neck or presqu'ile enclosing Black bay at low water, but completely covered at high. Between Wendover and Clarence are several islands known as the Horseshoe and Thurso islands. See plate 6.

ROCKLAND MILLS.

Above these is the town of Rockland, established by the two mills of the W. C. Edwards Company. These mills have created a thriving town; a branch line of the Grand Trunk railway, from South Indian, gives access by rail, and the Canadian Northern railway is under construction. In front of the mills are extensive wharves. The river is narrow here but very deep, so the current is not swift.

On the Quebec side of the river is the township of Lochaber settled in 1807 by Major McMillan's Highlanders. The principal town is Thurso, and through the township flows the Blanche river, which drains Echo lake and Whitefish lake and is about thirty miles long.

The south shore from Rockland to Ottawa is a narrow watershed about five miles wide, which drains to the Ottawa by small creeks. In rear of it is the basin of the

South Nation river. The land is low on the immediate river front, but rises quickly inland. The mouth of Green creek in Gloucester township is low and marshy.

The Nation is subject to spring floods, because there are no equalizing lakes along its course. At the end of April the river flows at the rate of 24,000 cubic feet per second, but early in the summer its discharge has shrunk to a couple of hundred cubic feet per second. As its flood has passed before that of the Ottawa begins, it has not to be reckoned with in the restraining reservoir system proposed. See plate 3.

Contrary to the general opinion, the clearing away of a forest does not necessarily produce floods. Snow in the woods not drifted, but lies in an even layer shaded from the suns of March and April. It, therefore, does not melt till the warm air, day and night in May melts it like a hot blast, and the snow is discharged suddenly into the streams, in conjunction often with copious rains.

The sources of both the Nation and Rideau rivers are to the south, and liberating slightly before their outlets, arrive on top of a gathering flood. Settlement too brings numerous bridges, each for economy, narrowing the clear way of the river. In ordinary years this does not matter, but when melting snows and falling rains unite to form an extra high flood, then each bridge becomes a partial dam and the flood level is raised a little higher than ever before known. The swamps too have been drained and no longer act as storage reservoirs.

TOWNSHIP OF GLOUCESTER.

The Billings were the first settlers in 1803, and it was surveyed in 1820. Billings bridge was the first one built across the Rideau river. Dug-out canoes were used because stronger than those of bark, but the bark canoe was used for light traffic.

In all these settlements the Yankees knew, what the British had to learn by experience, about clearing, fencing, building, stock raising and wintering, so they led the settlements and filled the posts of councillors, justices of the peace, &c.

The Nation river was settled from Glengarry and Cornwall. Nepean and Gloucester were settled about 1810, Goulbourn about 1819, and Osgoode among the last in Carleton. See plate 1.

Men working in the shanties observed and remembered the best tracts of land, which they took up as farms when they were able.

TOWNSHIP OF OSGOODE.

Osgoode was surveyed along the Nation by McDonald about 1825. It had very fine pine and oak. Grist was taken to Dickenson Landing. The township was cut off from the Bytown settlement as there were no roads, while the Castor and Nation rivers gave them a highway to the St. Lawrence. See plate 1.

The Bytown and Prescott railway was begun about 1853 through the efforts of Mr. Robert Bell, its president, and at one time editor of the *Packet* newspaper.

TOWNSHIP OF CUMBERLAND.

Robert Fraser of Cumberland introduced bob-sleighs. Previously timber hauling was done on only one sleigh, while the ends of the pieces trailed along the road. Much larger loads and greater economy were effected by Mr. Fraser's system, but it was only adopted after great opposition.

When the timber was being cleared off, there was a trade in potash from the burning necessary to clear the land for farming, and the revenue from this was considerable.

South Gower was surveyed in 1817; North Gower in 1826. Governor Simcoe's proclamation of free lands and the building of the Rideau canal attracted many settlers from the United States about 1831.

The flooding of the lands by the dams made for the canal is said to have produced malaria, and the country seems to have been unhealthy for some years. Smallpox broke out, and there were practically no doctors.

TOWNSHIP OF BUCKINGHAM AND LIEVRE RIVER.

On the Quebec side of the river a large area of the immediate shore is flooded every year during high water. It is thickly wooded with a growth of large elm. There is a good wharf at Masson, which serves the village of Buckingham, four miles inward, where the Maclaren lumbering industry is situated. A short branch connects the mills with the Canadian Pacific railway along the north shore. See plate 1.

Buckingham township was laid out in 1799, being, with Chatham, lower down, one of the two first townships to be surveyed. Through it flows the Lievre river, which is one hundred and sixty miles long. Its discharge is twenty-two thousand cubic feet per second in May, decreasing to fifteen hundred in September. The basin area of this river is four thousand square miles. The mean flow for a period of seventy-five days 1st May to 15th July, is about nine thousand cubic feet per second. It is used for power purposes, and a reduction in the flow below three thousand cubic feet per second would cause complaint. There are many lakes along the course of this river, which may be used as storage reservoirs to hold back the spring floods. A number of these lakes could be dammed and allowed to accumulate water till they rose eight feet, while, during that period, an average flow of five thousand cubic feet could be passed out every second. The combined areas of these reservoirs would be equivalent to eighteen hundred square miles one foot deep, or one hundred and eighty miles ten feet deep. See Appendix N, and plate 3.

The river is navigable from above Buckingham twenty miles to Poupore, where there is a lock and dam, by which boats can go twelve miles further up. Two serious landslides have occurred upon this river, one near the locks in 1904 and one at Salette in 1908.

Opposite Masson wharf is Cumberland wharf, which serves the township of the same name. The shore above Cumberland is low, and there are some islands opposite Daniston.

TOWNSHIP OF TEMPLETON.

The town of East Templeton is on the north shore, and at the wharf are large mills, owned by the East Templeton Lumber Company. The foreshore is low, and a long point encloses a bay similar to those at Papineauville and Thurso. The Little Blanche river flowing through the township has its rise in Grand and McGregor lakes, about twelve miles back. Phosphate mining was carried on in Templeton and Buckingham from 1874 for twenty years, but nothing is now mined, as the competition of the Georgia and Florida deposits have reduced prices to an unremunerative basis.

TOWNSHIP OF HULL.

Hull, although settled in 1800 by Mr. Wright in advance of any other place in the valley except Burrit Rapids, was itself slow in growing, but was the base for the district. Men engaged to work on some of Mr. Wright's farms till they learned for themselves, and the level, fertile lands of Templeton, Hull, Eardley and Onslow, in Quebec, and Gloucester, Nepean and March, in Ontario, attracted many people from the States, among whom were some United Empire Loyalists. The closeness of the mountain range to the north shore narrowed the fertile belt, but to the south were large areas of flat farm land. Hull too, being at the foot of an eight-mile barrier to navigation, carried on a transfer business for all the upper river, as the route from Hull to Aylmer was on the concave side of a great bend in the valley. The lumber shanty was everywhere the outpost from which the settlement sprang.

NORTH SHORE RAILWAY—Q.M.O. & O.

The first direct rail connection to Montreal was in 1876 by the Quebec government road, now operated by the Canadian Pacific railway, and the line was extended

as far as Aylmer. Previously the rail route to Montreal was via the St. Lawrence and Ottawa to Prescott, thence by the Grand Trunk railway. In 1887 the Pontiac Pacific Junction railway (now Canadian Pacific railway) was built west from Aylmer to Quyon, Shawville, Coulonge and Waltham, its present terminus, and in 1891, the Gatineau Valley railway gave connection up that river to Maniwaki from Hull.

TOWNSHIP OF NEPEAN.

The earliest settler in the township of Nepean was Rice Honeywell, 1810. He came from Prescott, and the next February married there and came down the Rideau on the ice to Hog's Back with an ox and 'jumper' sleigh. During the war 1812-14, Honeywell brought three barrels of flour from the St. Lawrence, because the price asked at Hull was too dear. He was forced to sell two barrels to neighbors, who gave him $50 per barrel.

RICHMOND SETTLEMENT.

The first store on the Ontario side was kept by Collins, opposite the foot of Victoria island; he sold to Bellows, who built a wharf about 1815 called 'Bellows' Landing.'

After the Napoleon wars the army was reduced, and officers and men of the Ninety-ninth and One Hundredth Regiments at Quebec, accepted land grants and chose Upper Canada in which to make new homes under their old flag. The party of colonists left Quebec July 28, 1818, upon the same day that the Duke of Richmond arrived, as governor, and so, filled with enthusiasm, they called their new settlement 'Richmond.' On their arrival at Ottawa, August 15, the name 'Bellows' Landing' was changed to 'Richmond Landing.' They camped on the Flats, and Collins' store supplied their needs until they organized themselves and cut a road through to Britannia, Bells Corners, and up the Jock. For some reason they preferred the banks of the Jock to the Rideau or the Ottawa. Shanties were built with great rapidity in the new settlement, and by Christmas the last tents were abandoned.

In 1819, the Duke of Richmond determined to travel over the Rideau Canal route so as to report to the Duke of Wellington. He arrived in August, 1819, and the Richmond colony gave him a grand reception, but it was noticed he became very agitated at the sight of water. On going to embark in a row boat down the Jock next day, he was seized with violent convulsions, and died of hydrophobia, contracted through the bite of a pet fox at Sorel. His body was taken to Quebec.

The township of March, surveyed 1823, was named after one of the titles of the Duke of Richmond—Earl of March. Prior to the survey the farms were taken up by mutual consent along the river front from Nepean to Torbolton, and the surveyors, John MacNaughton and Hugh Falls, ran lines afterwards. There was always a good fellowship and a strong patriotism throughout the settlement. The largest and best pines were reserved to furnish the navy with masts.

An average house was of logs, fourteen feet by twenty and eight feet high, with scoop roof, standing in a clearing of five acres fenced around with poles and brush. The bush was chopped down during winter and the land burnt off in spring, then a crop was hoed or raked in between the stumps. An acre then yielded forty bushels of wheat, sixty of corn or oats, and four hundred of potatoes. Among the settlers was a sprinkling of U. E. Loyalists, who helped greatly by their knowledge of bush farming, that had been begun in the United States a hundred years before. They knew all about oxen, stock-raising, agriculture and lumbering.

Lumbering was always the first industry taken up. The horses and cattle engaged in the business created a ready market for oats and hay, but, as the lumbering moved further and further up the river, the farmers had to seek a market up the

Madawaska and Bonnechere, driving their loads up and returning empty in from one to three weeks' time. This market eventually ran out, as the upper country was cleared and nearby farmers could supply the shanties.

In 1830, the people feared frosts as they formerly did in Manitoba, and there was anxiety, lest the grain crops would not be sufficient to supply the people's wants. Flour was $16 to $20 per barrel at times; cotton, 25 cents per yard; butter was sold for years at 10 cents; beef, 3 cents to 4 cents, stall fed, 7 cents.

In the early days wild pigeons and other game were very plentiful. It was necessary to import pork to supply the large demand for the lumber trade. Chicago was not in existence, but it came from Cincinnati. Beef was sometimes salted and kept in wheat straw. Pemican was never used in the eastern country.

Bad roads forced both rich and poor to make the journey to Brockville, Perth or Prescott on foot, and carry home their purchases on their backs. In winter several grists would be taken to the mill on one ox sleigh. There is a story told that the settlers turned out *en masse* to find a lost darning needle because it was the only one.

In 1833 the Richmond road was only a track between stumps.

In 1820 seed grain and potatoes were packed forty miles on men's backs. Sometimes a long journey on foot to procure the implements and hardware. or the first year rations granted by the government, would result in an empty handed return. Either the supplies were not available or a bumptious agent refused them out of caprice. 'Man's inhumanity to man.'

Grist was often taken across Aylmer lake to Wright's mills or to Britannia .and there was also the Sheriffs mill at Chats rapids, and later, one at Richmond.

Richmond village on the Jock, a branch of the Rideau, was the commercial center for years before Bytown, which was then only Richmond Landing.

BYTOWN.

Development at the site of Ottawa city was slow. In 1816 John Burrows took up the first land grant, and in 1826 sold the area between Sparks street and Laurier avenue, and eastwards from Concession street to Nicholas Sparks for $400. This was then wild swamp land, a creek flowing east along what is now Slater street, and there were three houses near the falls.

The advent of the Royal Engineers to construct the canal in 1827 was the origin of Bytown. In the beginning of that year 'nothing could be heard but the clinking of hammers in building houses, the noise of drills boring rocks and a perfect cannonade of blasts.' In 1832, Bouchette describes the village as well laid out, with wide streets, and having 150 houses, mostly wooden, 'many of neatness and taste.'

The Imperial Union Bill, 1840, included Bytown as of sufficient importance to be represented in the United Parliament of Canada, and Lord Sydenham recommended it as the seat of government. The population in 1845 was 7,000, but it fell off during the great depression in the lumber trade that followed, recovering about 1850, when the number was 6,000. Telegraphic communication was established with Montreal about 1850, and there were two sawmills, one grist mill, four founderies, an ashery, seven tanneries and four breweries. There were three banks besides loan and insurance companies, also eight schools and three newspapers. The population in 1870 was 25,000.

In 1859 the central block of the parliament buildings was begun ,in pursuance of Lord Sydenham's recommendation, (1841), as the seat of legislature for the United provinces of Ontario and Quebec, and at federation, 1867, the central building was taken over and two others similar to it were put under construction.

AYLMER.

Aylmer, owing to its easy accessibility from the upper river, was for many years before railways were built, the county town of Ottawa county. The court house was built there 1852, but destroyed by fire and rebuilt 1865; in 1895 the county seat was removed to Hull.

QUIO, FITZROY AND CHATS.

Above Ottawa the lumbermen began to penetrate and in their wake came settlement. The roads to their shanties became the travelled roads and people took up farms along them. In this way the townships of Onslow, Bristol, and Clarendon were opened up at an early date.

Quyon was originally a North-west post during that company's flourishing period and, after 1820, was still kept by the Hudson's Bay Company. Bouchette describes it in 1832 as a dilapidated dwelling and an Indian trading store.

Fitzroy Harbour opposite Quyon originally settled by the Shiriff family (1818), who came from Port Hope. They explored the Chats rapids and his sons also explored the Ottawa-Georgian Bay route for the British Government. The first development of power was on the Ontario side of the Chats Falls, 1825.

By 1850 a horse railway had been made on the Quebec side to transfer the lumbermen's freight from one steamboat to another and Mr. Egan had a sawmill in operation.

The Chats Falls flow over a spur of the Laurentians that extends across the river southwards to Galetta. The rugged top of this spur forms a number of small rocky islands covered with pines and hardwoods that at once suggest Thousand Islands scenery. An Archaean outcrop either in the St. Lawrence basin, along the coast of Nova Scotia or between Vancouver island and the Mainland always produces the same delightful landscape.

CHATS CANAL.

A canal to surmount these falls was begun through the efforts of the Hon. John Egan, about 1854, but never completed. Its projected length was 2·8 miles, with six locks 190 feet x 45 feet x 7 feet depth on sills. The total lift would have been 49·8 feet. The expenditure was $483,000. A. P. MacDonald & F. Schram were the contractors.

Above Chats falls, Arnprior lake is pent up and near its lower end the Madawaska enters from the southwest. This river is very rough in its upward stretches and, till 1835, defied the attempts of lumbermen to gather its rich pine treasure, Opeongo lake, in the beautiful Algonquin Park 2,000 square miles, constitutes the headwaters of the river and also of the Muskoka, Petawawa, Bonnechere, Amable du Fond, Maganatawan and South rivers.

ARNPRIOR.

At the mouth of the Madawaska is the thriving town of Arnprior, 4,500 population, surrounded by a fine agricultural and grazing country and largely supported by the McLaughlin milling industries.

A Highland Chieftin 'The McNab' obtained a grant of the land in the vicinity in 1823, and Bouchette, 1832, mentions his residence 'Kinnell Lodge' as then in existence. In 1831 the Buchanan Brothers secured from Chief McNab a mill privilege and saw and grist mills were erected, the village being named after their native town in Scotland. These mills were sold to McLaughlin Brothers and rebuilt and enlarged in 1850.

The Bonnechere enters from the west a few miles above Arnprior draining Golden lake, which lies 18 miles south of Pembroke. Castleford a small hamlet is at the mouth but six miles above is the considerable town of Renfrew at the second chute

where the Canadian Pacific crosses the iver. Till 1874, Renfrew was the terminus of the pioneer railway, the Canada Central, now Canadian Pacific main line.

PORTAGE DU FORT.

Following up the Ottawa past Chenaux island is Portage du Fort, a settlement of some antiquity, Bouchette states, 1832, that the portage was one quarter of a mile long over white marble, with only 'Bissetts Chantier' and clearing, which was, however, much frequented by traders and voyageurs as a stopping place. This place as before stated, was the head of navigation on Arnprior lake. In the early times the Indians did not pass this way but landed below Chenaux island and portaged up into Catherine, Town and Olmstead lakes, then down into Muskrat lake where Cobden now is, continuing through the Muskrat river to the present site of Pembroke. This was a short cut and avoided the many strong rapids met between Portage du Fort and Coulonge lake, in following the main river.

This short cut was the route taken by Champlain in 1613 and, in 1867—Confederation year—Captain Overman of the Union Forwarding Company found a small ship's instrument, an astrolabe, lost by the celebrated discoverer. Champlainfixed his position at the foot of the portage but made an error and continues his error by dead reckoning, up to Pembroke, which was the end of his journey tha year.

ROCHER FENDU AND CALUMET.

From Portage du Fort to Coulonge lake, the river divides around the east and west of Calumet island, for here the river's course is almost south. The west branch is the Rocher Fendu channel almost a continuous rapid through a rock cañon. The east branch flows over the Grand Calumet falls at Bryson and the d'Argis (Bouchette, 1832) rapids and Mountain chute.

BRYSON AND COULONGE.

Ae the head of the Grand Calumet, opposite the village of Bryson, is the monument to Cadieux made from the marble of the vicinity.

Above Bryson the river is narrow and shallow but navigable to the Grand Marais flats at the head of Calumet island and through Coulonge lake.

Fort Coulonge is mentioned by Bouchette (1832) as a Hudson's Bay post and agent's residence. He also states, that at that date, lumber contractors had penetrated to the Allumettes lakes.

PEMBROKE.

Pembroke has a population of six thousand and, for a long time, has been known as the capital of the upper Ottawa. It was, as before explained, the head of the Indian short trail from Arnprior lake, being at the mouth of the Muskrat and Indian rivers where they unite and fall into the Ottawa. There was an Indian village on the site in 1613 when the first whites—Champlain's party—visited it and were entertained by the Chief Tessoüat, who had cultivated a garden. Here too, it was that Vignau confessed to the falsity of his statement, that, two years previously, he had been to Hudson bay and seen British ships attacked and the crews killed and eaten by cannibalistic Indians.

Champlain held a pow-wow with the Indians and went no further that year but retraced his journey to Montreal. This is said to have been the first assembly of its kind in Canada; it at least, was the first in the Ottawa valley.

The first settlement of Pembroke was in 1825 when emigrants from Miramichi, N.B., came to found new homes after the disastrous fire of 1825, naming the village Miramichi, after their old home. In 1828, Peter White and his family paddled their

way up from Bytown, the journey occupying 14 days. A daughter born that same year is said to have been the first white child born in the locality.

The first mill was erected by W. A. Moffat, 1840, and the site of the present town was divided into lots.

In 1850, the township of Pembroke had a population of 420 and the village possessed a saw mill, a grist mill and residences of persons connected with the lumber trade. At this date Ottawa was endeavouring to attract mill owners to the Chaudiere, as the completion of the St. Lawrence canals five years before, had changed the traffic route and cut deeply into business prosperity.

The basin of the Ottawa was little known in 1850 because immigration did not pass that way. Only one-eighth was organized into townships, which contained a very sparse population. Another eighth would include all the extent lumbered over, therefore three-fourths was wholly unoccupied, except by the remnants of Indian tribes, and unknown, except to a few Hudson's Bay traders.

RAILWAY DEVELOPMENT IN THE OTTAWA VALLEY.

Into this wilderness however a potent force was on the eve of entry. Steam had already won to civilization the lower valley, through the transportation facilities offered by the steamboat but a new application of this wonder-working steam—the railway—was coming. It was capable of transporting, not only up river and into the tributaries but also across the valleys and into adjoining ones, thus gaining almost the very doorsteps of settlers and carrying, not only in summer, but through the frosts and snows of the severest winter.

The following railways were in operation in Canada in 1850:—

Montreal-Lachine.	8 miles.
Champlain and St. Lawrence (St. Johns to Rouse Point).	43 "
St. Lawrence & Atlantic (Laprairie to Sherbrooke). . . .	95 "
Montreal and New York (Caughnawaga to Mooers. . . .	32 "
Grand Trunk (Toronto to Norval).	27 "

Besides this, 628 miles were under construction, of which the Prescott to Bytown railway, 54 miles long, was nearly completed.

In 1857 the project for a railway along the north shore of the Ottawa took shape and twelve miles from Carillon to Grenville were built but the projector died and nothing more was done. It remains a broad gauge to the present day. See page 516.

The necessity for a railway in the Ottawa valley was great and, in 1847, Mr. T. C. Keefer the veteran engineer of Ottawa published an article to advocate a road from Montreal to Toronto, in which he said. 'If Montreal, the natural market for Bytown does not exert herself the latter will make no great effort to avoid a connection with Ogdensburg, N.Y. which is only half as far as to Montreal.'

ST. LAWRENCE AND OTTAWA RAILWAY.

The first steam railway built in the Ottawa valley was the St. Lawrence and Ottawa, south through the Rideau watershed to a junction with the Grand Trunk main line at Prescott and to a connection by boat with the American system at Ogdensburg. This road was completed in 1854 and served as the only route to 'the Front,' and Montreal, till 1871. Its opening was coincident with the advent of mill industries to the Chaudiere Falls (1851-57) and a branch extended around the western part of the town to the lumber district.

CANADA CENTRAL RAILWAY.

The more important development, however, was westward, through the main valley. This began with the Canada Central (Brockville and Ottawa) railway from Ottawa

to Carleton Place and thence to the Grand Trunk at Brockville. There was also a branch from Carleton Place to Sand Point (1871) where connection was made with the Union Forwarding Company's steamers to Portage du Fort and Pembroke.

Lumber supplies now began to be carried in winter, men and horses were carried by rail instead of making the long up-river journey through the snow. The line was soon extended westward to Renfrew (1874) and then enthusiasm began to be shown toward the, so far, little understood transportation by rail.

Pembroke desired the advantages of a railway and a deputation interviewed the Canada Central manager and arranged to give free right of way and $75,000 bonus for an extension to their town. Work was completed about '76 and till 1881, Pembroke enjoyed the prestige of a terminus but the Pacific road was taking form under government management. It was intended to extend westward from Renfrew, following the Bonnechere, passing 20 miles south of Pembroke and south of Lake Nipissing. Influence was at once set on foot to prevent this, the argument that 30 miles of railroad were already built, being pressed. The extension was made from Pembroke and the main river secured the Pacific road to Mattawa and North Bay. Pembroke later secured a grant to recoup it for the $75,000 bonus given to the original Canada Central Company. The railway at once changed the whole district and branch lines and improvements have followed and many more will yet ensue. North Bay was nothing in '78, now it bids fair to be the distributing point for a Northern Territory larger than the original upper Canada of the Iroquois conquest (1650).

FRENCH RIVER.

From North Bay the navigation route crosses Lake Nipissing to the head of the French river. The shores are rock and the river entrance is filled with islands that again recall the Thousand Islands of the St. Lawrence.

The Chaudiere Falls of the French river are wildly grand scenery, the descent being 20 feet into a lake stretch 9 miles long called in Indian Ho-chick-awa-chick or Las des Jeunes Maries as an Indian wedding party is said to heve perished in crossing. Into this reach flows the Restoul river from the south and the Wolseley from the north. The latter extends almost to the west arm of Lake Nipissing where the flourishing Monnette settlement has sprung into existence during the last few years.

At the foot of the lake the French river divides around Eighteen-mile island, the north channel extending down 5 miles on the same level like a narrow rock-bound bay. There is then a succession of falls and rapids for two miles with almost mountain scenery on either side. Below this is a long river stretch widening into occasional lakes, down to Dry Pine lake where, by a 7 foot fall, it reaches the main French again.

The main river below Lac des Jeunes Maries is a succession of rapids for five miles. Below is a magnificent river stretch bordered by bold rock shores with deep narrow bays resembling Norkeigan fjords. Eighteen-mile island forms the north bank and, though wild and rugged along the river, there are a few good farms further in.

INDIAN LEGENDS.

Two Indian legends are associated with this reach of river, which were related to the writer by the Old Chief Pe-ta-wachuan (I hear the rapids far away) known and respected for many years as 'Chief Duckies' of Chaudiere portage. Half-way down the reach on the north side, is a great obelisk-like rock, that much resembles a huge owl and, in the river, are three small rock islands. Their existence is thus accounted for. Once, long ago, a great hunter of fabulous skill gave chase to a huge owl and three owlets. These he pursued night and day till, in desperation, her little cnes becoming exhausted, she threw them into the water, where they instantly became rock

peaks, while the mother perched on the bank and turned to stone still guarding her brood.

Near the foot of the reach is the opening scene of the other tragedy. Here, an ancient land slip has led to the fanciful tale of another great hunter, who was camped with his family near by when a monster beaver, as shrewd and wicked as he was powerful, stole the hunter's child and retreated to his dam. The infant's piteous cries proclaimed its whereabouts and the frantic father began an attack that breached the dam, as the slide authenticates, but not before the wily beaver managed to escape with the baby and take up a fresh stand behind a curious rock outcrop, some 15 miles up river in the Five-mile rapids. Hither the father pursued and again disloged the beaver, and this time abandoned the child and beat a hasty retreat across Lake Nipissing and through Trout lake to a rocky hill between Turtle and Talon lakes. There the beaver was killed with great rejoicing, the whole tribe gathered to feast upon his carcass, but, cut up and in the boiling pot, the tail still splashed the water into foam finally upsetting it, forming Pine lake, which sure enough is 10 feet above all its surrounding neighbours. No squaw to this day lets the beaver meat boil over either, be it known.

At the foot of Eighteen-mile island the French river is really a lake, whose area is very much diminished by groups of islands. There are two outlets, that by the main river flows through a rock cañon beneath the Canadian Pacific bridge and over the Recollet falls about seven feet, continuing on with but two very small rapids to the level of Ox lake.

It is difficult to say whether the falls were named after the Recollet Fathers or after a small bird of very similar name.

PICKEREL RIVER.

The outer outlet is to the east of Cantin island, at a place called the Horseshoe. It flows down the Pickerel river, parallel to the main French and about one to two miles south of it, into Ox lake, where they rejoin. It was down the French river that Champlain and his followers made their voyage in 1615 to Lake Huron, and eventually into the Trent valley. So long a time has elapsed, even since the river was abandoned by the fur-traders, that no legend or evidence of those stirring days remains.

Lac de Bœuf—or Ox lake for short—is an extensive area with steep rocky shores and many small rock islands, covered with spruce and hardwood. Besides being the terminal pond for the French and Pickerel rivers, it also receives the waters of the Wanapitei or Hollow Tooth river. The lake discharges itself by seven outlets, that over the Dalles rapids being the principal one and leading directly into the best harbour of them all. French river harbour was originally explored for deep navigation by the late Mr. Walter Shanly, who proved that, despite report to the contrary, the inlet was deep and well suited for a navigation entrance.

At present the French river is entirely devoted to lumbering enterprise, and a couple of steam tugs have been hauled up over the Dalles rapids and the Horseshoe falls to work on the two lower stretches of the river. There are also large mills with workmen's residences forming French River village upon the south shore of the harbour.

THE SQUARE TIMBER TRADE.

The first step in a lumber enterprise was to obtain a limit from the Crown. They were rented by auction, the area being usually 10 miles square, and, in 1870, the rental was from $1 to $2 per square mile, with an additional charge of one cent per cubic foot on square timber and ten cents per standard sawlog of 12 feet length and 21 inches diameter. The Crown rented 31,600 square miles of forest in 1867, deriving a revenue of $361,670.

Having secured the limit, it was explored by bush rangers and a site selected for a shanty, which was built of round logs with a central fireplace or 'camboose.' A wooden crane supported the cooking kettle, and the open fire not only served for cooking but gave heat and light to the men, whose berths were ranged along the ralls. Provisions were carried up by steamboat and pointer boat in the autumn, augmented latr on by the sleigh loads, hauled, sometimes, 200 miles over ice and snow roads. The supplies were simple:—pork, flour, beans, tea and rough clothing.

There were three grades of workmen:—timber hewers, whose wage ran from $20 to $25 per month; teamsters and 'swampers,' or road makers at $10 per month for their first year.

The tree having been felled and hewn square was hauled to the nearest creek, and everything prepared for an immediate start when the ice began to move. On the smaller and more rapid tributaries, the timber was floated through by booms of loose pieces till reaching the larger stream, cribs could be formed. These were not over 26 feet wide to allow of passing the various slides, and only a single timber in depth compared with a draft of 5 feet for St. Lawrence rafts. Each crib was held together by 'traverse' pieces across the top, and upon these, four 'loading sticks,' the largest and longest timber, were held between wooden pins driven into the traverse pieces. As few holes were bored in the timber as lossible, of course, and, in the earl ydays, birch 'withes' were employed to tie the pieces together; the twisting of these withes was quite a trade.

At first fifty cribs were secured together to form a raft, but, during the seventies and eighties, as many as two hundred cribs were massed together. On arrival at each of the twelve large raipds between Mattawa and Montreal the raft was broken into separate cribs, each of which was run singly and re-rafted at the foot. On the St. Lawrence rafts were run in large sections, and, owing to deeper draft and the heavy oak sticks they carried, 'whites' were always used. Sails were more used on the St. Lawrence than on the Ottawa where the lakes were less open to winds.

MAGNITUDE OF THE TRADE.

A pamphlet on the lumber trade of the Ottawa Valley, dated 1871 (anonymous) states that 'during the last few years' eighty million cubic feet had been cut in Canada, of which thirteen million dollars worth was exported, over half going to the States. Then fifteen thousand men were employed in the woods, and ten thousand in the mills. The transportation of timber from Quebec employed a fleet of twelve hundred large ships. Most of these were driven out of business by the Plimsoll Act, although their cargo was light, buoyant wood, and their practical sea-worthiness for that trade was attested by their purchase and use for many years after in carrying timber from Norway to Great Britain.

The Hon. J. K. Ward states in the 'Canadian Record of Science' that, forty years before, fifty wooden ships were built at Quebec, and that eighteen million cubic feet had been exported in one season. In 1894, however, only three million cubic feet of square timber went out, as the trade had changed to sawn lumber, which was handled at Montreal.

Intendant Talon made the first shipment of timber from Canada in 1667, just two hundred years before confederation, and one hundred years before Watt's patent for the steam engine.

Philemon Wright opened the raft trade in the Ottawa valley, 1806, and then had a saw mill for his local needs, but the earliest mill was built at Point Fortune, 1790. Mr. Ward describes it as having one upright saw, and, so slowly did it cut, that the owner could eat his dinner while a board was being detached. Modern band saws detach a board in four seconds.

The square timber trade received a great check in 1825 when the British duties on Baltic timber were lowered. Many small men were ruined, and only the strong

firms survived; but, with the mania for building railways in Britain culminating in 1845, the demand for timber became very brisk, and each year saw a greater output. In 1845, nearly twenty-eight million cubic feet came to Quebec, and twenty-four million was exported. All might still have been well, but, not knowing the prospective demand—for there were no cables, but only slow packets to give news of the markets—the lumbermen brought thirty-seven million cubic feet to Quebec to supply a demand of only twenty-four million (1846), and prices fell to a ruinous degree. In 1847 the left over and fresh supply amounted to forty-five million cubic feet for a demand of nineteen million, and, in 1848, thirty-nine million cubic feet were presented but only seventeen million sold.

Three causes are given for the evident over-production in Canada, the first being erroneous government regulations that required large quantities of timber to be cut each year off each limit leased. The second was a threatened reduction of the area leased from 100 square miles to 50, so that lessees pushed forward the cutting in order to have the cream off the large area. Thirdly, imperfect surveys caused disputed boundaries and encroachments, with consequent appeals to physical force. Firms, therefore, placed large gangs of picked men in the field, to fight if necessary, but certainly to make timber for their keep and wages. The large profits of 1845, however, must be considered the main incentive to the over-production.

Dues were collected on square timber at so much a stick, whether it was sixty feet or only twenty feet long. Only big timber, therefore, was cut, and soon the limit was abandoned for a fresh location, but this meant a new beginning and perhaps the loss of a good depot farm as well. A decreasing profit then, and a diminishing supply of large trees, led to the idea of manufacturing the smaller pine and shipping out sawn lumber.

SAWN LUMBER INDUSTRY.

Sawn lumber has completely replaced the square timber trade in the Ottawa valley. The saw mill, beginning at Point Fortune and St. Andrews, jumped to Hull, then, as each settlement began, a local saw mill was required, the most notable being the Hawkesbury mills which, remain among the largest in Canada.

It was between 1850 and 1858 (Crimean War, Indian Mutiny and California Gold) that the Chaudiere mills at Ottawa were established by the advent of a number of American lumbermen, who were interested largely by Mr. G. M. Thompson. The reports of Mr. Wright's success at Hull had determined Mr. Thompson to emigrate in 1810 and build the first Chaudiere mill on the Ontario side.

Exports of sawn lumber were impossible till the Grenville and Carillon canals were built, for, unlike hewn timber, it could not well be rafted and floated to market. At the present day only one great manufactory of sawn lumber is in operation at Chaudiere, the improved railway communication having made it possible to manufacture much further up the river and still get the product economically to market.

CHAUDIERE MILLS IN 1870.

For a description of the Chaudiere saw mills at their prime, the following from an anonymous pamphlet (1871) is well worth preserving:—

'In this division of our subject we propose to lay before our readers an accurate and interesting description of some of the largest lumber factories in the Ottawa Valley, more especially those of the Chaudiere, from which some idea may be formed of the magnitude of this, the staple trade of Canada, and its great importance to the country at large, on account of the numerous branches of industry connected with and dependent upon this trade. The establishments described in this pamphlet are engaged chiefly in the export trade; they are in full work usually about five months of the year, from 1st of May to 1st October, and although much of the machinery employed is self-acting and labour saving to an extraordinary degree, a large

number of hands are also employed. There are besides these larger establishments numerous smaller mills scattered over the country, wherever favourable locations and water powers are to be found, and engaged generally in local trade. In addition to the large amount of capital actually invested in the lumber trade, its importance to the country cannot be over estimated, because the whole of the industrial pursuits connected with it, such as for the maintenance of workmen and their equipment, must be carried on in the immediate neighbourhood.'

'At the Chaudiere a series of well devised hydraulic works, have rendered available for manufacturing purposes a fall of about twenty-nine feet, and as the lowest water ever known gave a discharge of 13,500 c.f.s., the power would be equal to 33,956 horse-power; in high water the discharge is equal to 125,000 with a mean fall of sixteen feet, which is equal to 168,145 horse-power.'

LOGS CUT, WAGES AND SUPPLIES.

The consumption of sawlogs by each of the six firms at Chaudiere, 1870, was about one hundred and fifty thousand, equivalent to thirty million feet of lumber. This required:

450 men getting out logs,	300 men and teams.
300 men piling and forwarding,	

The average number employed by each firm was 637 men, receiving $306,000, so that the whole six firms employed an industrial army of 4,000 men, paying them annually nearly two million dollars, all spent in the neighbourhood for their sustenance.

The supplies required for the season in getting out 150,000 logs were:—

825 bbls. pork,	75 boxes axes, 1 doz. each,
900 bbls. flour,	60 cross-cut saws,
500 bush. beans,	225 sleighs,
37,000 bush. oats,	3,750 lbs. rope,
300 tons hay,	1,500 boom chains, 7 ft. each,
3,750 gals. syrup,	45 boats,
7,500 lbs. tea,	900 pairs blankets,
1,875 lbs. soap,	15 cookeries,
1,000 lbs. grindstones,	375 cant-dogs.
6,000 lbs. tobacco,	

Costing, at a low estimate, about $54,367.50.

The principal exporting establishments of that day (1870) with a short description of each is appended:—

BRONSON AND WESTON.

This firm was established in 1853, and was the first to take up land at the Chaudiere for the purpose of establishing a sawmill on a large scale.

They are now proprietors of two large saw-mills, a carding and grist-mill, lath and splitting mills, and own a large tract of land used as a piling ground—the whole premises extending from near the wooden bridge to the point of the island. They get out annually about 175,000 logs, producing between 30 and 40 million feet of lumber, of which from 5 to 10 million feet are always kept on hand.

The large mill contains 2 stock gangs, of 30 to 40 saws; 2 slabber gangs, 14 to 16 saws; 2 Yankee gates, 32 saws; 1 single saw; with the necessary butting and edging saws. The smaller mill contains 1 slabber gate, 1 stock gate, and butting and edging saws.

The wheels employed are Rose's improved and the Lamb wheel.

The lath mill contains 2 gangs for sawing laths, 5 or 6 saws each; a butting apparatus and picket saw; and a splitting mill for slabs; and produces 10 millions of laths.

In addition to their saw mills this firm have an extensive grist and carding mill. They employ for six months of the year, in shipping the productions of these mills, 26 barges with 5 men each, 4 steamboats, 9 men each, in all 222 men.

It requires $3,000 to pay the weekly wages of the employees of this establishment.

A. H. BALDWIN.

Commenced business here in 1853 and owns two saw mills, a machine and blacksmith shop, and a ship yard for building barges.

He gets out annually about 125,000 logs, making 25,000,000 feet of lumber, and employs in the larger mill, 1 large slabber, 24 saws, 1 stock gang, 40 saws, 2 Yankee gates, 32 saws each, and 2 butting and edging tables; in the smaller mill there are 2 Yankee gates, 1 edger and 1 butter. The wheels employed are Rose's improved.

He also owns 14 barges, 2 steam tugs, and one steam barge, manned by 80 men, and gives employment throughout the year to about 400 men.

The ship yard, which has been in operation for about four years has turned out 16 barges and one steam barge, whose engines were made in the machine shop, owned by Mr. Baldwin, and employs 12 to 15 men.

Mr. Baldwin sawed and shipped the first lumber for the American market from the Chaudière, and in company with Messrs. Harris, Bronson & Co., brought the first logs down the Ottawa from Des Joachims and also himself brought down the first logs from above that point.

J. R. BOOTH.

This gentleman first established business at the Chaudière in the year 1858 by the manufacture of laths, and now carries on extensive operations in sawing pine lumber. His mills are situated on the south shore of the Ottawa, just below the falls, and manufacture annually from 26 to 30 million feet of pine lumber, of which 12 to 15 million feet are always on hand on his piling grounds, which cover a space of about 10 acres of land.

These mills are fitted with gang and circular saws as follows:—

Three gangs containing 40 saws; 3 slabber gangs containing 18 to 20 saws; 1 Yankee gate containing 36 saws; 1 large circular saw for dimension timber; and a large number of circular saws for butting and edging.

The power employed is derived from the waters of the Chaudière, assisted by 14 Rose's improved water-wheels, 2 for each gate, and upright and central discharge wheels.

This establishment gives employment in the winter time in the woods to about 850 men and 300 teams, and in the summer time at the mills to 400 men and 40 teams.

Mr. Booth gets out 3 or 4 rafts of square timber in the season.

E. B. EDDY.

Carries on the largest business in the manufacture of the products from our forests, on this continent, converting the timber of his enormous estates into every description of useful article from saw-logs and lumber to wooden ware and lucifer matches.

The business was first established in 1854 when Mr. Eddy commenced his operations in this section of the country, by manufacturing matches; and such are the resources of the valley of the Ottawa, and the immense advantages of the water power of the Chaudière, that he, with the characteristic energy of his race, has been enabled to build up a business on a gigantic scale, the productions of which are of vast utility to the people of this continent.

We give here the annual productions of these mills and will speak more fully of the processes of manufacture hereafter.

Eddy's mills and piling grounds cover a large tract of land on the north shore of the Ottawa, at the Chaudière Falls, and extend from the falls to the island opposite the parliament buildings. They consist of one large pail factory built solidly of stone; a match factory also of stone; four saw mills of great extent built principally of wood, and numerous other buildings, offices, &c., necessary to such extensive operations, including a sash, door, and blind factory, and a general store.

In addition to these mills Mr. Eddy has built a double track over a mile in length, which runs from his mills to the further extremity of his piling grounds, and enables him to distribute and pile the enormous amount of lumber produced, most expeditiously.

These mills manufacture annually about 40 million feet of pine lumber, of which there are always from 8 to 10 million feet in the piling grounds. They also manufacture annually 600,000 pails, 45,000 wash tubs, 72,000 zinc wash boards and 270,000 gross of matches, besides the productions of the sash, door and blind factory.

The saw mills are fitted with gang and circular saws of all kinds and sizes, and the whole establishment gives employment to from seventeen to eighteen hundred persons, many of whom are girls employed in the manufacture of matches. In addition to these there are about four or five hundred men employed in the woods, where Mr. Eddy owns 'limits'—a tract of land of about 50 square miles in extent, the greater part of which is forest, but where there are some cultivated lands, and a growing village called Fort Eddy.

The force employed in driving the mills, is derived from the unlimited water power of the Ottawa, assisted by mechanical agencies of modern invention, and is equal to about 600 horse power.

THE EDDY MATCH FACTORY.

Consists of a range of buildings containing, two machine rooms, two dipping rooms, two large packing rooms, a warehouse and shipping office, besides engine house, drying rooms, &c.

In the machine rooms the wood is cut up by two different machines. The one, which is employed in making the best matches of seasoned wood, cuts up the blocks, already prepared, by means of fifteen small knives, which divide the wood into pieces the exact size of the match and then pass them through grooves into the separate divisions in the racks placed ready for their reception at the rate of 4,000 per minute from each machine.

These racks are pressed so as to place the small pieces of wood firmly in their position, and are taken to the dipping room. Each machine employes one man and one boy.

The dipping room for this class of match is divided into two compartments, in the first is a chaldron of molten sulphur, into which the racks are passed, each piece of wood receiving a certain quantity of sulphur. The racks are then taken to the other room and dipped into the final preparation of phosphorus, &c., and then placed in iron safes built into the walls all around the room to dry, which takes about two hours, when they are ready for packing.

In the other machine room wood is cut up on another principle by a machine which contains 9 knives and cuts the match into double the required length, at the rate of 340 strokes a minute, making 9 at each stroke, or 18 matches, equal to over six thousand a minute.

These sticks being of green wood are then placed in open boxes, and taken to a drying room heated by steam pipes. When dried they are rolled up in circular form between bands of wadding by machines, which distribute each separate piece of wood into equi-distant parts. The rolls are then taken to the dipping room, where they

are dipped on each end in the preparations of sulphur and phosphorus and hung up on racks to dry.

They are then cut in two by another machine and are ready for packing.

The packing rooms are divided into several compartments, and occupied entirely by girls, who are employed in packing the matches first in the small wrappers, (which they prepare from material supplied them, in their homes), and then into boxes of ¼ gross each which are taken to the warehouse and shipping room.

The factory gives employment to about 50 men and boys and about 90 girls.

THE PAIL FACTORY.

Is a large stone building of three stories high near the principal saw mill, where pails are manufactured at the rate of 2,000 pails and 150 wash tubs per diem. Every part is made by beautiful machinery. In one room the staves are sawn into regular sizes, in another the bottoms and hoops are manufactured, in another the handles are turned, and in another the various parts are joined together, planed and finished.

The pails are then taken to the painting room, where they are painted and grained by patent India rubber rollers. They are then finished off and fitted with handles after which they are packed in hay and made ready for shipment.

THE SAW MILLS.

Which are four in number and of great extent, contain every description of gang and circular saw numbering, in all 243 saws. The capacity of the mills is equal to the sawing of 200,000 logs per annum.

PERLEY & PATTEE.

This firm was established in the year 1857, and, has very extensive mills close to the Chaudiere Falls, with large piling grounds attached, through which are laid lines of rail for distributing and piling the lumber. They get out annually about 150,444 logs, producing 30 to 40 million feet of pine lumber, of which a considerable amount is kept always on hand. They employ a large number of men through the year; on an average, over 600. Their mills are furnished with 2 slabbing gangs of 40 saws each; 2 stock gangs of 40 saws each; 2 Yankee gates of 32 saws each; 1 single gate and 1 resawing gate, with the usual compliment of circular saws for butting and edging. The wheels employed are Rose's improved and the Lamb wheel, 1 pair to each gate.

LEVI YOUNG.

First established his business at the Chaudiere in 1854, and owns one saw mill, getting out and sawing about 100,000 logs in the year, producing about 20,000,000 feet of pine timber. He employs one slabbing gate of 40 saws; one stock gate of 40 saws; one Yankee gate of 32 saws, and the necessary edging and butting saws. The wheels employed are Rose's improved, 1 pair to each gate. In addition to this, Captain Young gets out annually about 3 rafts of square timber, employing through the year from four to five hundred men.

WRIGHT, BATSON & CURRIER—OTTAWA STEAM MILL.

These fine mills are situated in the village of Hull, (P.Q.) with 24 acres of land attached and enclosed, and with excellent piling grounds and shipping docks adjacent. The mills contain five gang saws, one large circular saw for cutting building timber, also saws for cutting laths, clapboards, &c. The capactiy of these mills from May 1st to December 1st is thirty million feet; the quantity usually cut averaging from sixteen to twenty-five millions. The timber limits belonging to this firm

are situated on the river Madawaska, and are six in number, containing in all 275 square miles. There are three farms on the limits, well stocked with cattle and provided with convenient buildings, offices, &c. The main depot is at Griffith, Renfrew, where there is a Post Office, also a general store, blacksmith and carpenter shops, &c.

The average number of men employed all the year round ranges from 250 to 300 exclusive of those employed in freighting lumber away.

THE GATINEAU MILLS.

The Gatineau mills, belonging to Messrs. Gilmour & Co., are situated at the village of Chelsea, about eight miles from the city of Ottawa and nine miles from the junction of the Gatineau with the Ottawa river. The scenery above and below the mills is exceedingly romantic and beautiful—four or five rapids and cascades, and sloping banks to the water's edge covered with trees and foliage render this portion of the river most picturesque and charming. The mills are situated on the south bank of the Gatineau above the high falls, and are surrounded by a series of booms and works of great magniture, upon which immense sums have been expended. The whole of the saw-logs which descend the Gatineau are caught in these booms, and a very faint idea can be conveyed to a stranger of the immense amount of skill required to separate those belonging to the Gatineau mills from those belonging to different manufacturers below.

During the summer this point of the river presents a scene of bustle of the most extraordinary kind, and as the firm employs literally an army of workmen, the scene can be better imagined than described.

Below the booms, the worst point of the river has to be encountered by the logs descending the stream, and it is frequently enlivened by the appearance of perfect islands of stranded timber, technically called jams, and the efforts of the owners to set them afloat exhibit scenes of daring and endurance seldom witnessed elsewhere.

The mills belonging to Messrs. Gilmour & Co., consist of two large substantial buildings, and a smaller mill for preparing lumber for the American market, and they were commenced about thirty years ago. The water power used is equal to about five hundred horse-power. There are 13 saw gates containing about 220 saws, and twenty edging, butting, and re-sawing circular saws. These mills will manufacture 230,000 feet, board measure, in eleven hours, or about 35 millions of feet per season. About one-third of this lumber is cut for the Quebec market, and the balance for the United States. Attached to the mills there are about three miles of wooden canal for conveying the sawn lumber to the piling grounds. Messrs. Gilmour & Co. possess timber limits to the extent of 1,700 square miles, whence they obtain the requisite number of saw-logs to supply these extensive works, and 1,000 men receive employment from them during winter and 500 in summer, including lumbermen, farmers, surveyors, &c., &c. They also employ 250 spans of horses and 80 yokes of oxen; and during each season they consume 40,000 bushels of oats, 600 tons of hay, 1,500 barrels of pork, and 3,000 barrels of flour, besides large quantities of clothing, boots, shoes, tea, tobacco, blankets, &c.. &c. These mills are amongst the most celebrated in the country, not only for the romantic beauty of the surrounding scenery but for the perfection of the machinery employed and the order and good management exhibited throughout them.

We must not omit to mention that upon their timber limits this firm has no less than nine farms, comprising in all about 1,500 acres; the land is excellent; as much as fifty bushels of wheat to the acre having been raised some seasons. Of course this is above the average, but the yield is generally excellent. The whole of the produce of these farms is consumed by the employees of the firm. On the banks of the River Gatineau they have four principal depots, from which supplies are sent

to the lumbermen at work in the woods. One of these is distant upwards of 200 miles from Ottawa. This firm pays from $275,000 to $300,000 in wages annually. Mr. Mather is, and has been for some years, the manager of the Gatineau mills.

LE MOYNE, GIBB & CO., BUCKINGHAM.

The mills and limits formerly owned by Messrs. Thomson & Co., are now the property of Messrs. Le Moyne, Gibb & Co. One of the partners, Mr. McPherson LeMoyne, resides at Buckingham, and personally superintends the whole business; he was also the managing partner of the late firm of Thomson & Co.

These mills are situated on the River Du Lievre, about four miles back from the Ottawa river, and in conjunction with the mills belonging to Messrs. Jas. Maclaren & Co., on the opposite side of the river, have control of one of the finest water powers in Canada; the falls are 70 feet in height, and the River Lievre being very deep and supplied by many large lakes in the north, there never is any scarcity of water, even in the driest summers. The timber lands and limits on the west side of the Lievre are held by LeMoyne, Gibb & Co., and those on the east by James Maclaren & Co.

The mills which are quite new, having just been rebuilt, are of large size and fitted with every modern improvement to save labour and to do good sawing; they have already cut up 125,000 logs between the 15th May and the 15th October. The business done at present is about 800,000 logs a year, which are sawn almost entirely into 3-inch deals for the Quebec market. A slide over two miles in length conveys the timber from the mills to the basin, where the thin lumber is taken out and piled and the deals are run into the water and rafted up into cribs.

All the logs sawed at these mills are made on the tributaries of the River du Lievre, which drains an immense extent of contry. The two firms that work on this river have, at their own expense, built very extensive slides to pass their logs over different falls, and also constructed many booms, piers, &c., at different points, the government never having expended anything on the River du Lievre for improvements of any kind, though the public have for very many years derived a large revenue from it.

HAMILTON & CO.—HAWKESBURY MILLS.

This is one of the largest as well as one of the best known of the great milling establishments of the Ottawa Valley. It is situated about 60 miles from Ottawa city on the south shore of the river near the head of the Grenville rapids. There are included in this establishment, four saw-mills together with a grist mill with four runs of stones for the production of flour for the use of the raftsmen, shantymen, and other employees, as well as for the neighbouring farmers. The mills contain 101 vertical saws and 44 circular saws, driven by 72 water wheels, and turn out from 35,000,000 to 42,000,000 feet of lumber per annum. About five hundred men and boys are employed constantly by the firm at Hawkesbury alone in summer. Some conception of the immense extent of the operations of this firm may be formed when we say that more than 3,000 tons of agricultural produce are consumed annually.

The Honourable John Hamilton resides at Hawkesbury, and the whole village and establishment bear evident signs of opulence and comfort.

The limits from which these mills obtain their supply of timber are situated principally upon the rivers Rouge, Gatineau and Dumoine. Messrs. Hamilton & Co., bring down from their limits 200,000 logs, on an average, annually.

THE PROCESS OF MANUFACTURE.

The saw-logs when got out of the forest are taken to the nearest point on the Ottawa, and left to be drifted down by the stream, each firm having a private trade mark on each log by which they are recognized. At the Chaudiere they are caught by booms spread across the river above the falls, and guided through the different slides to the respective mills where they are to be sawn.

At the mills the logs are hauled up out of the water by a powerful wheel always in motion, and so placed on the cradle which guides them through the saws.

There are various kinds of saws, each performing its particular duty in the process. The slabber-gate, which contains from 18 to 20 saws, cuts the outside of the log into boards of 1-in. thick, leaving the bulk in a slab of 14 inches in thickness, and of different width according to the size of the log, 37-in. being the largest. As the saw gets through the end of the log, these outside pieces are taken away and trimmed to the required size by the butter and edger.

The large slab is then turned over on the flat side and run through the stock-gang, which contains from 30 to 40 saws placed about 1-inch apart and sawing the slab into 1-inch boards. These saws can be changed at will to saw 2-inch or 3-inch boards. It takes these saws about eight minutes each to get through a log of the ordinary size. The Yankee-gate is a combination of the slabber and stock gate, and contains about 32 saws. This gang saws both ways, the teeth of the slabber facing one way and those of the stock the other. By this means the log is sawn by the slabber as described above and the slab turned over and sent back through the stock-gate, so that while the slabber gang is dividing one log the stock is finishing off another. The single saw is used for sawing the logs into pieces of about three inches square, the gate acting in the same way as the other gangs, but with only one saw which performs the whole work. These gangs are all worked on upright pivots, the machinery underneath forcing the gate up and down at a considerable rate on the same principle as the old sawpit fashion, where one man works on top of the log and another underneath.

The butting and edging tables are for the purpose of taking off the rough sides and ends of the planks as they come from the larger gangs, and are fitted with counter saws for this purpose.

The planks are laid on the table, and a revolving chain with catches in it carries the wood along past the circular saw which takes off the outside pieces leaving the plank the required width and length, and disposing of the waste and damaged wood.

As the planks pass over those tables the foreman marks each one according to its size, and they are then wheeled out on hand trucks to be taken to the piling grounds.

These piling grounds are of vast extent, and are in many cases supplied with railways over which the lumber is drawn in horse trucks; but in some cases the lumber is slid through a hole into a large trough of running water which carries it to its destination.

THE OTTAWA DISTRICT SLIDES AND BOOMS (1870).

The Government works connected with the descent of timber in this district are on the following rivers:—On the Ottawa, main river, 11 stations; on the Gatineau, 1; on the Madawaska, 15; on the Coulonge, 1; on the Black, 1; on the Petawawa, 31; on the River Dumoine, 11.

List of Slide and Boom Stations on the Ottawa River.

The distances given are measured on the latest maps, following the channel through which lumber is floated down the river:—

Names of Stations.	Distance from mouth of Ottawa, at Ste. Anne.
1.—Carillon	27 miles.
2.—Chaudiere (north side, Hull south side Ottawa)	98 "
3.—Chaudiere (Little)	100 "
4.—Remick	102 "
5.—Deschenes Rapids	104¾ "
6.—Chats Station	131 "
7.—Head of Chats	134 "
8.—Chenaux	152 "
9.—Portage du Fort	156 "
10.—Mountain	161 "
11.—Calumet	163 "
12.—Joachim Rapids	249 "

The works at these twelve stations consist of:—2,000 lineal feet of canal; 3,835 feet slides; 29,855 fet booms; 346 feet bulkheads; 1,981 feet bridges; 52 piers; 3 slidekeeper's houses, and 3 store houses.

The necessity for the construction of dams at certain additional points on the Ottawa, so as to afford the means whereby a more abundant supply of water can be obtained for use in the slides, is again urged by parties interested. The lumber trade of this district has now attained such increased proportions that the works on which the supply of water to the slides is dependent, which answered their purpose tolerably well while the trade was in its infancy, have become inadequate to perform the services required, the result being that during dry seasons the passage of timber through the slides is difficult, owing to the scarcity of water. His Excellency the Governor General was pleased, by order in council, dated May 18, 1870, to authorize the incorporation by patent of the Ottawa Improvement Company, a society formed for the purpose of effecting improvements on the upper waters of the River Ottawa, to facilitate the descent of timber, the company binding itself to adhere to certain specified conditions.

Gatineau River.—In ascending the Ottawa, the Gatineau is the first tributary possessing government works.

These works are all at one station, about one mile from its confluence with the Ottawa. They consist of. 3,071 lineal feel of canal; 4,138 feet booms; 52 feet bridge; 10 piers, and 1 slide-keeper's house.

Madawaska River.—The Madawaska is the second tributary in ascending the Ottawa, on which the government has provided works for the descent of lumber.

List of the names of slide and boom stations on the Madawaska, numbered from the mouth of the river upwards: 1. Mouth of river. 2. Arnprior. 3. Flat rapids. 4. Palmer island. 5. Burnstown. 6. Long rapids. 7. Springtown. 8. Calabogie lake. 9. High falls. 10. Ragged chute. 11. Boniface rapids. 12. Duck island. 13. Bailey chute. 14. Chain rapids. 15. Opeongo creek.

The works at these stations consist of: 1,750 lineal feet of slides, 18,179 lineal feet of booms, 4,080 lineal feet of dams, 182 lineal feet of bridges, 43 piers, 1 slide-keepers' house, and 1 work-shop.

The slide at High Falls sustained considerable damage in the spring of 1870, in consequence of the unprecedented height of the river, the water of which passing over the Nagle dam, caused a breach in that work, through which the debris, mingled with large quantities of logs, escaped. This mass, on coming in contact with the slide, tore down 500 feet of that structure. Efficient measures were taken for the reconstruction of a portion of the damaged work, so as to admit of the season's lumber being passed through. This accident and the generally decayed state of the slide,

will, it is feared, necessitate its being entirely rebuilt before the beginning of another season.

The Coulonge River.—The Coulonge is the third tributary in ascending the Ottawa, on which the government has placed slides and booms.

The following is a list of the government works on this river:—Boom at the mouth, 300 feet long, and one support pier. Boom at Romain's rafting ground, 400 feet long, an dthree support piers. Booms at head of High Falls slide, 1,848 feet long, and six support piers.

Black River.—Ascending the Ottawa, the Black river is the fourth tributary upon which works have been placed.

The works consist of:—1,139 lineal feet of single-stick booms, 873 lineal feet of slide, 346 feet of glance pier, 135 lineal feet of flat dam.

The Petawawa.—This is the fifth tributary in ascending the Ottawa, upon which government slides and booms have been made.

Seven miles from its mouth the Petewawa separates into two branches. On these seven miles there ar five stations; on th north branch there are eighteen stations, and on th south branch eight stations.

List of the slides and booms on this river, in the order in which they occur, from the mouth upwards:—1. Mouth of river. 2. First chute. 3. Second chute. 4. Third chute. 5. Boisdur.

North Branch.—1. Half-mile rapid. 2. Crooked chute. 3. Between High Falls and Lake Traverse (a slide and a series of dams and booms). 4. Thompson rapids. 5. Sawyer's rapids. 6. Meno rapids. 7. Below Trout lake. 8. Strong eddy. 9. Cedar islands. 10. Foot of Devil chute. 11. Devil chute. 12. Elbow of rapids. 13. Foot of Sault. 14. Middle of Long Sault. 15. Head of Long Sault. 16. Between Long Sault and Cedar lake (south shore). 17. Between Long Sault and Cedar lake (north shore). 18. Cedar lake.

South Branch.—1. First slide. 2. Second slide. 3. Third slide. 4. Fourth slide. 5. Fifth slide. 6. Sixth slide. 7. Seventh slide. 8. Eighth slide.

The work at these 31 stations are as follows:—

On the Main River.—2,963 lineal feet of slides, 8,469 lineal feet of booms, 2,077 lineal feet of dams, and seven piers.

On the North Branch.—380 lineal feet of slides, 2,671 lineal feet of booms, 1,131 lineal feet of dams, and 23 piers.

On the South Branch.—2,134 lineal feet of slides, 388 lineal feet of dams.

River Dumoine.—The sixth and last tributary of the Ottawa upon which the government works have been executed is the 'Dumoine.' The length of this river is about 120 miles, and it drains an area of about 1,600 square miles. It flows into the Ottawa from a northerly direction at a point about 256 miles above Ste. Anne. The works on this river consist of a pier and retaining boom at its mouth, a single stick slide, and a series of flat dams from the mouth upward. They may be detailed as follows, viz:—300 lineal feet of slide, 800 lineal feet of booms, 1,324 dams, and six piers.

Thanks are due Dr. Saulte, Mr. James Write, Dominion Geographer, Hon. J. K. Ward, Capt. Murphy and others who have kindly furnished much valuable information.

APPENDIX S.

THE GEOLOGY OF THE PROPOSED GEORGIAN BAY CANAL ROUTE.

The description of the geological formations found along the route of the proposed canal can for convenience be divided into three main sections, viz.: 1st. The portion between Montreal and the Chats falls, where the surrounding rocks are mostly of sedimentary (Palæozoic) character, composed of sandstone, limestone and shale; 2nd. That between the Chats and Des Joachims rapids, in which the rocks are for the most part crystalline with considerable areas of crystalline limestone and occasional outliers of Palæozoic rock in the near vicinity; and 3rd, that from Des Joachims by way of Nipissing lake to the mouth of French river, in which the rocks are mostly granite and gneiss, with small outliers of sandstone and limestone containing fossils, but in which the crystalline limestone is almost entirely absent.

From Montreal west in the first section, the sedimentary formations (Palæozoic) comprise the Postdam sandstone, Calciferous limestone with some shales, the former often dolomitic, the Chazy shale and sandstone succeeded upward by the Chazy limestone, the Black river limestone, and the Trenton limestone. To the south several miles, newer formation such as the Utica, the Lorraine and the Medina, comprising mostly shales and sandstone occur, but they do not show along the Ottawa river.

The first of these, the Potsdam, which rest on the granite and gneiss at a number of places, is well seen at the village of Ste. Anne, west of Montreal, and at several points around the shores of Lake of Two Mountains. It passes up into the Calciferous by passage beds through the addition of calcareous matter so that the sandstone becomes a limestone which through the pressure of the magnesia is generally dolomitic. The sandstone is well seen below the mouth of River de Graisse at Rigaud, and the limestone on the north shore below the mouth of North river. These rocks are overlaid at Carillon by the Chazy. The sandstone is similar in character to that found in Nepean which is extensively quarried for building stone and used in the parliament buildings at Ottawa.

All the formations lie nearly horizontal except along the line of contact with the crystalline rocks when they become somewhat inclined. Above Grenville the Potsdam sandstone is again seen at Montebello, and in a quarry between this place and Papineauville on the north side of the river, where it is also overlaid by the calciferous. At Templeton also there is a well defined ridge of these rocks between the railway (C.P.R.) and the village street and they continue west to the mouth of the creek, three miles east of Gatineau Point. Above the Chaudiere they again appear in the strip between Graham's Bay and Barry's wharf, and the last outcrop of the Potsdam in this direction is in a small quarry in rear of Quio village. At all these places the stone is well adapted for quarry work, the formations lying nearly flat.

The Chazy is again seen at different places on the Island of Montreal and reappears again along the Ottawa at Carillon continuing thence to Grenville. It is divided into two portions, a lower consisting of greenish-grey shales with beds of sandstone, and an upper composed largely of limestone. The portion of the canal between Grenville and Greece's Point shows the lower part of the Chazy very well. Some of the heavier sandstone beds are well adapted for building stone and the rock is used to some extent for dry walls. The limestone often occurs in heavy bands and is extensively quarried in places, one of the largest of these along the Ottawa being at

Little Rideau in Ross's quarry, and further west in Butler's, four miles west of L'Orignal. From these a large amount of stone was taken for the construction of the Grenville canal.

Exposures are by no means numerous along the shores of the lower Ottawa, the banks being often composed of clay, but the Chazy again shows near Clarence and Rockland and also at Cumberland, above which to Ottawa it is seen at the base of the escarpment which extends thence almost to Ottawa city. West of Ottawa it is well exposed at Barry's wharf and thence continues to the vicinity of Fitzroy Harbour on the south side of Lake Deschenes, while on the north side it comes in just west of Tetreauville, is well developed about the town of Aylmer, and continues along the shore to the mouth of Breckenridge creek, where it meets the granite. It again outcrops in the town of Quio and continues nearly to the foot of the Chats falls where it is underlaid by the Calciferous formation.

The Black river formation which passes up into the Trenton is well seen near Rockland in the large quarry, (Stewarts) on the face of the bluff west of the village. Here the rock at the bottom is Chazy, the quarry itself is largely in the Black river formation, and the upper portion is in Trenton limestone. A ridge composed of these three formations extends thence to Ottawa. In this on the Montreal road south of Ottawa in the upper or Trenton portion are large quarries (Robillard's) which supply stone for the city to a large extent.

The city of Ottawa is in part built on Trenton limestone which crosses the river into Hull. The Black river formation appears at Remicks rapids in the western part of Mechanicsville, and underlies the village of Tetreauville, where several well defined faults break across the formations. Further west both Trenton and Black river rocks are seen to the south of Buckham bay and a large quarry has been opened on the top of this ridge from which stone was taken for the construction of the bridges along the line of railway north of the river and for the locks of the proposed canal past the north side of the Chats Falls.

On this stretch of the river the crystalline rocks occur at several points. They cross the Ottawa at Montebello showing on the south side in a hill at the ferry landing where gneiss and quartzite, associated with crystalline limestone, affords a fine section. At Rockland also they again cross the river and on the south side are exposed at the base of the Potsdam near the shore at the mills. At Buckingham they are seen at the falls of the Lièvre on the post road, but do not cross. These rocks form ridges along the north shore which extend from below Lachute to Calumet where they come near the shore, and from this to the Gatineau are separated from the Ottawa by a narrow margin of the Potsdam and Calciferous formations. West of the Ottawa they form the north shore from Breckenridge creek nearly to the Quio. On the south side of Lake Deschenes a ridge of granite and gneiss, with diorite and crystalline limestone, extends from Fitzroy Harbour east to the township of Nepean.

East of Ottawa the country between the Ottawa river and the St. Lawrence is uniformly low. There are no marked elevations with the exception of Rigaud mountain, and the country is so level in many places that the head-waters of the Nation river take their rise within about two miles of the St. Lawrence not far from the town of Brockville. In this area the soil is generally excellently adapted for agriculture, but there are several large areas of peat bogs which are now being utilized to some extent for the manufacture of compressed peat fuel.

The country below Ottawa for some miles along the north side of the river is celebrated for its mineral wealth. Here are the great mines of mica, apatite, graphite, &c., which are among the most productive yet found in Canada. Iron also occurs at several places and has been mined to some extent, and deposits of felspar, generally of the red variety, and found near Templeton and north of Gatineau Point, which have been quarried, but the high charges for freight to the market in the United

States have seriously affected the output and for the present these are closed. Attempts to mine asbestos have been made at sveral places, notably at Perkins Mills in rear of Templeton, and near Pointe du Chene, but the percentage of fibre was in both cases found insufficient to render the enterprise profitable. In the same way the output of apatite or phosphate of lime, which at one time assumed large proportions, was abandoned owing to the discovery of the phosphate deposits in Carolina and Florida, where phosphate could be mined and shipped at so low a figure as to render the mining of the Quebec apatite an impossibility. Large quarries of excellent granite have been opened on the south flank of the mountains north of St. Philippe, and quantities of the stone are shipped to Montreal and elsewhere, and quarries of crystalline limestone were at one time worked near the village of Lachute. The other quarries along the river route have already been referred to.

Ascending the river, between the Chats falls and Portage du Fort, the rock on the north side of Chats lake are mostly of the crystalline series, comprising granite, gneiss, diorite and crystalline limestone. About Norway Bay there are heavy deposits of sand and small outliers of Calciferous limestone appear on several of the islands in the channel above Arnprior. In the lower part of the lake, on the north side, are situated the Bristol iron mines which occur in a belt of diabase rocks with schist. The iron is somewhat sulphurous, and was mined some years ago quite extensively, the sulphur being removed by burning the ore in specially constructed kilns. The ore is found in large pockety masses, there being no well defined vein in so far as can be learned. Work has been abandoned at this locality and the mines have been idle for some years.

On the south side of the lake the crystalline limestone extends from the head of the Chats to Arnprior. It is cut across by dykes of red and white granite. At Arnprior extensive quarries have been opened in a handsome banded variety of marble and large quantities have been taken out, some of the decorative pillars and slabs in the Ottawa Houses of Parliament being obtained at this place.

Above this the Calciferous and Chazy formations again reappear and extend to the mouth of the Bonnechère, where they again give place to the crystalline series which continues thence up to the Rocher Fendu channel along the south side of Calumet island.

In the limestone of Portage du Fort several quarries have been opened, and have produced a very handsome stone for decorative work. Some of the pillars in the House of Commons at Ottawa are from this place; and another quarry, opened a couple of miles north on the road to Bryson, has produced a beautiful white dolomite of which large blocks can be obtained. The work at all these quarries is of an intermittent nature, the present difficulty of shipment interfering somewhat with their constant operation.

From Portage du Fort to Bryson the limestone and granite extend all the way, the latter cutting and altering the former. Large masses of greenish diabase or gabbro also occur in the eastern portion of Calumet island, and here are located the mines of silver-lead and zinc blends which were worked quite extensively several years ago but closed apparently on account of litigation.

Above this the north or Bryson channel shows outcrops of granite at several points but there are deposits of sand and clay, the former often forming shifting sand bars between the head of the island and Campbell's Bay during the high water in the river. These sandy shores extend around the west end of the island to Gower Point. On the west end of Calumet island there are ledges of the Chazy and Calciferous formations which thence extend up the river above Fort Coulonge and show along the shores in this direction at Pointe Sèche and on the west side of the cove or bay east of the boom, where they pass up into the Black river limestone. At Pointe Sèche there are quarries in the limestone which has furnished stone for building purposes.

At the boom the crystalline rocks again come to shore and are exposed for a short distance till concealed by sands and clays, but along the north channel past Allumette island, they are again exposed and continue to Fort William where they are again concealed by drift along the low points opposite High View.

The Rocher Fendu channel on the south side of Calumet island is rough, broken by several falls and heavy rapids, where the crystalline limestone is broken across by masses of red granite. No minerals of importance are known along this stretch of the shore but attempts were made several years ago to open a supposed deposit of nickel ore a couple of miles above the head of Rocher Fendu lake. The deposit has proved of no practical value. Masses of granite and diorite cut the limestone in all directions and the rocks as a rule are much altered. Above Sullivan's island the shores are of clay, and from this to the bend at Paquette rapid there are large areas of drift, principally sand.

Here the sedimentary rocks again come in a basin extending across from the Pembroke shore. These flat lying beds are well seen at the southeast corner of Allumette island and on Hawley island, and are Chazy limestone passing down into Chazy shale. They occupy the whole south side of Allumette island, but the greater portion of the interior is covered with heavy deposits of sand. To the south side in the direction of Musquash lake and outlet the Black river limestone again appears and quarries in this rock, which caps the Chazy formation, are opened near Graham station on the line of the Canadian Pacific railway. The Calciferous limestone again appears above the town of Pembroke but this also disappears near the town line of Alice township.

Above this a heavy reef of granite extends across to near the head of Allumette island. On the main land these rocks outcrop at the mouth of the Petawawa river, above which to the mouth of Chalk river the shores are composed of cliffs of sand from 30 to 60 feet high. These sands form extensive areas to the south in the direction of Chalk river station and along the shore of Sturgeon lake.

The portion of the Ottawa between High View and Des Joachims rapid is known as Deep river. The bottom of this part of the river is supposed to be below sea level and the north side is bordered by high ridges of granite and gneiss for the whole distance, except where concealed by drift deposits. These are well seen at Indian Point above the mouth of the Schyan river. The south side of the river is much lower than the north and generally drift covered, though the underlying rocks are granitic.

It would appear from the great depth found in this river at some points and from the occurrence of the Palæozoic formations at so many places in the bed of the stream that the old valley of the Ottawa represents a period of great erosion, since the channel was evidently excavated before the deposition of the sedimentary rocks from the Potsdam up.

Between Des Joachims rapids and the mouth of the Ottawa several changes of level have taken place in past age. This is indicated by the presence of terraces, sands and clays, and old river channels, which have since been filled up by the drift deposits and have forced the river to make other channels for the Ottawa waters. Among these old channels several may be here indicated.

At Des Joachims the original course of the river was evidently by a channel now partly filled by drift, which reached the foot of the rapids by way of McConnell lake and stream, through the depression now seen to the north of the village. Another old channel evidently turned off from the present stream about fifteen miles lower down in a depression to the south which communicated with the waters of Sturgeon lake and thence to the river in Allumette bay some two miles south of the point known as High View. Into this old channel the water of Chalk river now empties. Another old channel evidently extended directly east from the town of Pembroke along the valley of Musquash creek and lake, from which the course can be traced east of a series of depressions dotted by a chain of small but sometimes very deep lakes to the present

channel on Chats lake near the Chenaux rapid several miles above the mouth of the Bonnechère river.

Above the City of Ottawa indications of another old channel are seen which turned off to the south of Fitzroy Harbour and extended by way of the Carp river to the vicinity of Shirley bay; while opposite the city of Ottawa another channel, now marked in part by Brewery creek, passed in rear of the city of Hull. To the south of Ottawa, judging from a line of deep borings in the clay, another channel extended from the lower part of Rideau canal to the main river near L'Original.

From Des Joachims westward to Mattawa the rocks along the river are mostly of the crystalline variety. No limestones of this series appear in this direction, these having terminated apparently near the mouth of the Black river opposite the lower end of Allumette island. At several places, however, newer rocks of Chazy and Black river age are seen, as at Deux Rivières and not far from Klocks, both sandstone and limestone, the latter at one time being used for lime-burning, and the former for the manufacture of grindstone. At Mattawa there is clear evidence of an old channel which extended from the Mattawa river a short distance above the village, and connected with the main channel at the foot of the rapid about three-fourths of a mile below.

Thence westward along the Mattawa the rocks are all of the crystalline series chiefly of granite and granite-gneiss. A small outcrop of crystalline limestone is seen near the foot of Talon lake and at the Talon Chute. This is of good quality and has been used for lime burning to some extent. These limestone have been cut across by masses of red granite, which shows a finer texture along the line of contact. In places the rock is serpentinous and many portions would make an excellent building stone.

On Lake Nipissing also small outcrops of the crystalline limestone are seen as on the east shore of Great Manitou lake where it occurs with a massive red granite-gneiss. The limestone here is sometimes of pinkish colour with small plates of biotite mica. Otherwise the rocks around the lake are granitic with the exception of small outliers of Black river limestone, holding fossils, which are found on several of the Manitou group of islands. These rocks are both sandstone and limestone and are the lowest of this series in this direction. From this lake to the mouth of French river the rock is mostly of the granite-gneiss variety with a general absence of limestone.

It is not considered necessary in this place to enter into details as to the orgin of the several rock groups which have been described in preceding pages. The gneiss and granite west of Pembroke is usually regarded as representing the oldest portion of the crystalline series of the archean, sometimes known as the fundamental gneiss formation. Further east where the series of banded gneiss, with quartzite and crystalline limestone, is exposed the formation is regarded as of more recent date, and is known under the names of Hastings or Grenville series, and as probably representing the lowest portion of the great Huronian system. There is evidently a great physical break between these rocks and the next in order of succession are the Potsdam sandstones, since the great bulk of the Huronian and Cambrian rocks, seen elsewhere, are not recognized. While there have evidently been great periods of depression and of elevation throughout the whole extent from Lake Huron to the St. Lawrence it would appear that for a very long interval the surface was permanently elevated above sea-level so that the intervening formations between the gneiss, quartzite and limestone of the Grenville series and the Potsdam sandstone were not deposited. Subsequently the subsidence along the lower Ottawa at least was more regular since there are no visible breaks in the scheme of geological formations to the top of the Medina at least.

(Sgd.) R. W. ELLS,

Geological Survey Department.

MEMORANDUM REGARDING MINERAL DEPOSITS.

The mineral deposits along the route of the proposed Georgian Bay Canal, are alluded to throughout the foregoing report by Dr. Ells, on the geology of the section of country to be traversed. The industries at present active, however, are confined to those exploiting deposits of mica, felspar, graphite, granite and limestone used in cement manufacture. One iron mine also is to be added to the producing list, which is situated on the Kingston and Pembroke railway. In this latter belt of country considerable activity was exhibited in the past in the exploiting of numerous bodies of magnetite iron ore, but with the exception of the above-mentioned mine, all have been idle for many years.

The very extensive and flourishing cement industry situated in Hull, Que., would be a heavy contributor of freight whilst the corundum industry in Renfrew county would doubtless add to the business offering.

Considering the country lying northerly from the above route in the district of Nipissing, allusion need be made only to the Silver-Cobalt mines of the Cobalt camp and to the pyritiferous copper deposits found in the Lake Temagami district nor should the iron ore ranges of the same district be overlooked. Although these latter ranges are not as yet being worked, great hopes are entertained that with further exploration, extensive bodies of pure ore may be located giving a basis for extensive industries such as have grown up along similar ranges on the United States shores of Lake Superior.

Passing westerly mineral deposits situated within reach of the shores of Lake Huron and Superior may properly be considered in this connection.

Among these may be specially mentioned the well known nickel-copper industry of the Sudbury district as well as the operations of the Algoma Steel Company at Sault Ste. Marie.

Throughout this stretch of country bordering the upper lakes from the Parry Sound district on the east to Lake Shebandowan on the west are numerous deposits of sulphuret copper ores, an interesting feature being the recent re-opening of the Bruce Mines group of veins so extensively opened up in past years.

The mineral ore bodies of the country back of Port Arthur and Fort William have been recognized for a long period, the gold mining industry of the Lake of the Woods and Rainy River districts being of long standing and a number of bodies of sulphuret copper ores and of ores of iron having also been found there. A smelter for utilizing the iron ores of the Atik Okan range has been recently completed on the shore of Thunder Bay between Port Arthur and Fort William.

(Sgd.) ELFRIC DREW INGALL,
Mining Engineer to the Geological Survey.

APPENDIX T.

NOTES REGARDING TIME CONSUMED BY VESSELS IN PASSING THROUGH CANADIAN LOCK AT SAULT STE. MARIE, ONT.

The Canadian lock with its approaches at Sault Ste. Marie resembles more closely in all its features the type of lock and approaches as designed for the Georgian Bay Ship Canal than any other known structure serving a similar purpose; for that reason a comparison of them may be made as follows:—

Lock.	Chamber length.	Width.	Depth on Sills.		Lift.
			Upper.	Lower.	
	Ft.	Ft.	Ft.	Ft.	Ft.
Soo	900	60	*22·2	*20·3	18
Georgian Bay Ship Canal	650	65	22	22	10 to 50

* Below lowest known water level at construction.

The time consumed in passage through the St. Mary's Falls' canal, Mich., and data relative to lockage therein, both being expressed in speed in miles per hour, will be found on plate No. 36.

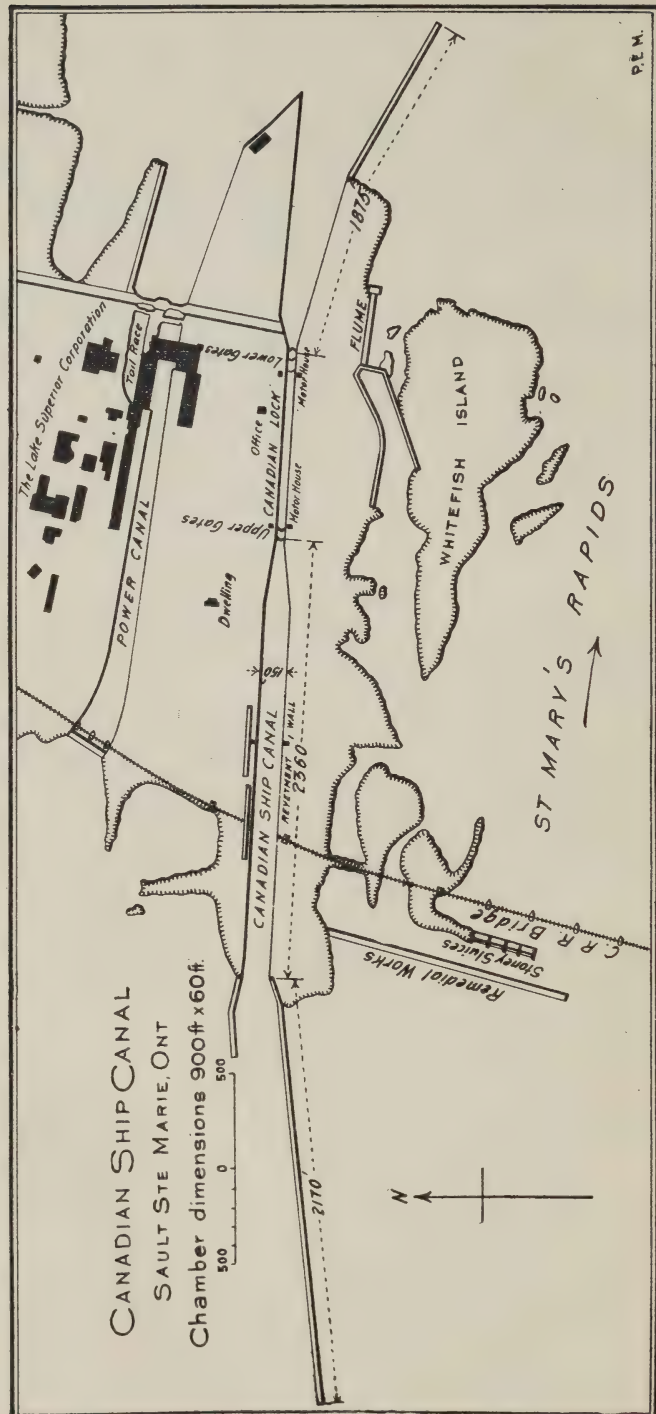
In order to obtain similar data with reference to the Canadian canal and lock, the following records of the passage of different steamers therein were completed for this office by F. B. Fripp, C.E., Resident Engineer for the Department of Railways and Canals, at Sault Ste. Marie, Ont.

Passage of Steamer 'Turret Cape', October 27, 1908.

Turret Cape—Up bound—light, length over all 258 feet, beam 44 feet, draft 13 feet 9 inches, net registered tonnage 1,142 tons.

Locked from mooring at North Pier, lower entrance.

	H.	M.	S.
Bow passed lower gates	10	57	30
Stern passed upper gates	11	15	15
Time elapsed locking		17	45
Stern passed upper gates	11	15	15
Stern passed upper end revetment wall	11	18	55
Time elapsed from lock		3	40
Distance in feet, 2,360 ft. Rate of speed, 7·3 miles per hour.			
Stern passed upper end of revetment wall	11	18	55
Stern passed end of south pier	11	21	45
Time elapsed		2	50
Distance, 2,170 feet. Speed, 8·7 miles per hour.			
Stern passed upper gates	11	15	15
Stern passed end of south pier	11	21	45
Time elapsed from lock		6	30
Distance, 4,530 feet. Rate of speed, 7·9 miles per hour.			


CANADIAN SHIP CANAL
SAULT STE MARIE, ONT
Chamber dimensions 900ft x 60ft
500
0
500
The Lake Superior Corporation
Tail Race
Lower Gates
Office
CANADIAN LOCK
Motor House
Motor House
Upper Gates
POWER CANAL
Dwelling
150
CANADIAN SHIP CANAL
REVETMENT WALL
2360
2170
1875
FLUME
WHITEFISH ISLAND
ST MARY'S RAPIDS
C.R.R. Bridge
Stoney Sluices
Remedial Works
N
P.E.M.

SESSIONAL PAPER No. 19a

Passage of Steamer 'Juniata,' October 27, 1908.

Juniata, passenger and freight, net registered tonnage 2,619, up bound, 1,747 tons package freight, length over all 361 feet, beam 45 feet, draft 17 feet 9 inches.

Locked from mooring at North Pier, lower entrance.

	H.	M.	S.
Bow passed lower gates	14	45	5
Stern passed upper gates	15	4	25
Time elapsed locking		19	20
Stern passed upper gates	15	4	25
Stern passed upper end revetment wall	15	9	20
Time elapsed		4	55

Distance, 2,360 feet. Rate of speed, 5·5 miles per hour.

	H.	M.	S.
Stern passed upper end of revetment wall	15	9	20
Stern passed end of south pier upper entrance	15	12	30
Time elapsed		3	10

Distance, 2,170 feet. Rate of speed, 7·8 miles per hour.

	H.	M.	S.
Stern passed upper gates	15	4	25
Stern passed end of south pier	15	12	30
Time elapsed from lock		8	5

Distance, 4,530 feet. Rate of speed, 6·3 miles per hour.

NOTE.—Passage after leaving lock all clear.

Passage of Steamer 'Hendrick S. Holden', October 29, 1908.

Hendrick S. Holden, net registered tonnage 3,091, down bound, 7,616 tons iron ore, length over all 430 feet, beam 50 feet, draft 19 feet 4 inches.

	H.	M.	S.
Bow abreast station. 102.00	11	6	10
Bow abreast end revetment wall	11	11	5
Time elapsed		4	55

Distance, 1,450 feet. Rate of speed, 3·4 miles per hour.

	H.	M.	S.
Bow abreast end of revetment wall	11	11	5
Bow passed upper gates	11	19	55
Time elapsed		8	50

Distance, 2,360 feet. Rate of speed...., 3·0 miles per hour.

	H.	M.	S.
Bow abreast station. 102.00	11	6	10
Bow passed upper gates	11	19	55
Time elapsed		13	45

Distance, 3,810 feet. Rate of speed, 3·1 miles per hour.

	H.	M.	S.
Bow passed upper gates	11	19	55
Stern passed lower gates	11	42	40
Time locking		22	45
Stern passed lower gates	11	42	40
Stern abreast end south pier, lower entrance	11	48	20
Time elapsed		5	40

Distance, 1,870 feet. Rate of speed, 3·7 miles per hour.

J. H. Bartow, bulk freighter, net registered tonnage 5,021, down bound, 9,500 tons iron ore, length over all 525 feet, beam 54 feet, draft 19 feet, 10 inches.

Passage of Steamer 'J. H. Bartow,' November 10, 1908.

	H.	M.	S.
Bow abreast end of south pier, upper entrance	11	5	45
Bow passed end of revetment wall	11	13	10
Time elapsed		7	25
Distance, 2,170 feet. Rate of speed, 3·3 miles per hour.			
Bow passed end of revetment wall	11	13	10
Bow passed upper gates	11	24	30
Time elapsed		11	20
Distance, 2,360 feet. Rate of speed, 2·4 miles per hour.			
Bow abreast end of south pier, upper entrance	11	5	45
Bow passed upper gates	11	24	30
Time elapsed		18	45
Distance, 4,530 feet. Rate of speed, 2·7 miles per hour.			
Bow passed upper gates	11	24	30
Stern passed lower gates	11	57	15
Time elapsed locking		32	45
Stern passed lower gates	11	57	15
Stern passed end of south pier, lower entrance	12	5	10
Time elapsed		7	55
Distance, 1,870 feet. Rate of speed, 2·6 miles per hour.			

NOTE.—Passage all clear.

Passage of Steamer 'Joseph Sellwood,' October 27, 1908.

Joseph Sellwood, net registered tonnage 5,269, up bound, 9,000 tons coal, length over all 545 feet, beam 55 feet, draft 18 feet 6 inches.

	H.	M.	S.
Bow abreast end of south pier, lower entrance	12	49	25
Bow passed lower gates	13	7	15
Time elapsed		17	50
Distance, 1,870 feet. Rate of speed, 1·2 miles per hour.			
Bow passed lower gates	13	7	15
Stern passed upper gates	13	52	55
Time elapsed locking		45	40
Stern passed upper gates	13	52	55
Stern passed upper end revetment wall	14	5	10
Time elapsed		12	15
Distance, 2,360 feet. Rate of speed, 2·2 miles per hour.			
Stern passed upper end revetment wall	14	5	10
Stern passed end of south pier, upper entrance	14	12	25
Time elapsed		7	15
Distance, 2,170 feet. Rate of speed, 3·4 miles per hour.			
Stern passed upper gates	13	52	55
Stern passed end of south pier, upper entrance	14	12	25
Time elapsed		19	30
Distance, 4,530 feet. Rate of speed, 2·6 miles per hour.			

NOTE.—Rate leaving lock at upper entrance slow owing to meeting down bound boat between swing bridge and end of revetment wall.

The variety of class of carrier, length, beam, draft and net registered tonnage will be observed.

From the following it would appear that the time elapsed in lockage bears a definite relation to the registered tonnage.

Steamer.	Registered Tonnage.	Time.	
	Tons.	Min.	Sec.
Turret Cape	1,142	17	45
Juniata	2,619	19	20
Hendrick S. Holden	3,091	22	45
J. S. Bartow	5,021	32	45
Joseph Sellwood	5,269	45	40
Average	3,428	27	39

While this is in a sense speculative, it fairly represents the average condition within the lock, but of course it is understood that the average elapsed time of vessels entering and clearing the canal is very much greater, probably taking between an hour and one and one half hours owing to their being obliged to wait for their turn, and the crossing or passing of other vessels in the approaches.

(Sgd.) S. J. CHAPLEAU.

APPENDIX U.

EXTRACTS OF A REPORT BY MR. J. E. WALSH REGARDING TRADE STATISTICS.

CANADIAN GRAIN TRADE, LAKE PORTS AND MONTREAL.

For statistics of Northwest crops, see page 567.

The total number and capacity of Canadian and United States vessels carrying grain from Fort William and Port Arthur during the season of navigation, May 7 to December 12, 1904, were:—

Canadian—Number, 38; capacity..	3,260,000 bushels.
United States—Number, 16; capacity..	2,815,000 "

Whilst the United States vessels equal only about 30 per cent in number, the carrying capacity was over 46 per cent of the total, an evidence of economy due to the operation of larger vessels.

During the season of 1905 the grain business at Fort William was divided as follows:—

46 Canadian vessels, capacity..	3,775,000 bushels.
46 United States vessels, capacity..	7,025,000 "

During the season of navigation 1906 there were:—

56 Canadian vessels, capacity..	4,757,000 bushels.
48 United States vessels, capacity..	9,336,000 "

In 1908 there were:—

77 Canadian vessels, capacity..	7,322,000 bushels.
45 United States vessels, capacity..	11,295,000 "

engaged in carrying grain from Fort William and Port Arthur.

(NOTE.—The *Wm. P. Snyder* (United States vessel) loaded 380,260.50 bushels of wheat in 1906, the largest cargo of grain ever carried on Lake Superior.)

The number of Canadian and United States steam vessels trading on the lakes and rivers between Canada and the United States (exclusive of ferriage) which arrived during the fiscal year ending June 30, 1904, at Fort William and Port Arthur, was:—

——	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian....	96	113,760	1,769
United States....	149	281,774	2,708
Port Arthur—			
Canadian....	184	331,735	10,887
United States....	370	176,642	5,842

The passenger steamers of the Canadian Pacific Railway, the Northern Navigation Company and the Algoma Central, increase the Canadian tonnage, without furnishing any great amount of space for bulk freight.

The number of Canadian and United States vessels (steam) which departed from Fort William and Port Arthur during the fiscal year ending June 30, 1904, were:—

—	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	74	116,405	2,301
United States	158	285,284	3,703
Port Arthur—			
Canadian	86	120,736	3,672
United States	370	176,642	5,845

Arrivals during fiscal year ending June 30, 1905, were:—

—	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	114	165,631	1,159
United States	229	263,558	4,564
Port Arthur—			
Canadian	79	95,559	2,647
United States	332	184,648	5,843

Departures:—

—	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	96	157,220	2,728
United States	242	324,159	4,619
Port Arthur—			
Canadian	32	42,643	1,121
United States	332	184,648	5,833

Arrivals during fiscal year ending June 30, 1906, were:—

—	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	95	144,260	2,040
United States	263	564,782	5,206
Port Arthur—			
Canadian	369	446,490	12,177
United States	291	161,796	5,820

Departures:—

——	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	123	202,647	3,671
United States	262	564,632	5,284
Port Arthur—			
Canadian	84	111,888	2,940
United States	291	161,796	5,093

Arrivals during nine months ending March 31, 1907, were:—

——	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	60	79,752	986
United States	163	354,611	3,163
Port Arthur—			
Canadian	197	259,781	6,566
United States	185	245,914	3,556

Departures:—

——	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	79	128,038	2,398
United States	160	341,236	3,081
Port Arthur—			
Canadian	118	150,448	3,764
United States	197	257,535	3,759

Arrivals during fiscal year ending March 31, 1908, were:—

——	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	77	153,300	1,529
United States	229	535,725	4,848
Port Arthur—			
Canadian	89	112,589	2,328
United States	313	539,292	6,394

Departures:—

—	Number.	Tonnage Register.	Number of Crew.
Fort William—			
Canadian	75	130,177	2,015
United States	234	529,223	4,884
Port Arthur—			
Canadian	109	150,101	3.782
United States	321	633,095	6,706

From this it will be seen that the preponderance of tonnage in this particular trade at these ports is in favour of the United States.

The following is a summary of British vessels employed in the coasting trade of the Dominion of Canada which arrived at or departed from Fort William and Port Arthur in the years mentioned:—

—	Arrived.			Departed.		
	Number.	Tonnage. Register.	Number of Crew.	Number.	Tonnage Register.	Number of Crew.
Fiscal y ar ending June 30, 1905.						
Fort William	469	629,478	13,094	476	623,187	12,925
Port Arthur	383	509,292	11,909	430	562,208	13,435
June 30, 1906.						
Fort William	477	612,288	13,840	451	571,399	12,167
Port Arthur	432	574,560	13,392	715	908,744	22,619
Nine months ending March 31, 1907.						
Fort Wi. iam	325	426,690	10,575	308	394,609	8,419
Port Arthur	297	280,526	9,493	564	488,410	12,280
Fiscal year ending March 31, 1908.						
Fort William	547	755,678	15,773	622	811,887	16,305
Port Arthur	545	725,360	16,644	521	684,478	15,937

Shipments of wheat and other grain from Fort William and Port Arthur by vessel and all rail for nine crop years ending August 31, 1908, were as follows:—

Crop Year.	—	Vessel.	Rail.	Total.
1899–1900	Wheat	16,086,582	2,263,247	18,349,829
1900–1901	Wheat	5,791,222	677,289	6,468,511
1901–1902	Wheat	27,180,204	968,524	28,148,728
	Total grains	27,793,200	1,554,172	29,347,372
1902–1903	Wheat	38,426,856	3,060,680	41,487,536
	Total grains	40,036,223	3,508,623	43,544,846
1903–1904	Wheat	28,552,625	2,831,526	31,384,151
	Total grains	28,897,667	3,122,414	32,020,081
1904–1905	Wheat	27,734,871	1,934,236	29,669,107
	Total grains	28,444,645	2,528,693	30,973,338
1905–1906	Wheat	49,627,267	5,882,453	55,509,720
	Total grains	54,438,527	8,209,482	62,648,009
1906–1907	Wheat	51,719,952	3,129,697	54,849,649
	Total grains	64,314,134	5,881,745	70,195,879
1907–1908	Wheat	37,925,996	9,595,494	47,521,490
	Total grains	47,743,336	14,364,177	62,107,513

During the season 1903, Canadian vessels carried to Canadian ports, 27,868,420 bushels; United States vessels carried to United States ports, 6,842,573 bushels. During 1905 Canadian vessels carried 29,334,881 bushels of wheat, of which 2,050,540 bushels were taken to foreign ports, whilst United States vessels carried 11,218,882 bushels to United States ports. Total wheat to Canadian ports, 27,284,341 bushels; total wheat to United States ports, 13,741,504 bushels. During the season of navigation 1906, Canadian vessels carried 27,924,429 bushels of wheat to Canadian ports and 4,053,905 bushels to foreign ports. During the same period United States vessels carried 12,398,003 bushels to foreign ports. In 1907 the total shipments of wheat by Canadian vessels were 37,446,696 bushels, of which 32,827,280 bushels were for Canadian ports and 4,619,416 bushels for United States ports. United States vessels carried 9,658,849 bushels during the same period.

Summary of shipments for the years 1906 and 1907:—

Total Shipments by Vessel.	1906.	1907.
Wheat	44,376,338	47,105,545
Other grains	6,807,377	12,705,274
Total	51,183,715	59,810,819
Wheat to Canadian ports	27,924,429	32,827,280
Wheat to foreign ports	16,451,909	14,278,265
Other grains to Canadian ports	6,710,247	11,599,157
Other grains to foreign ports	97,130	1,106,117

It will be observed that over thirty-two per cent of the 1906 shipments went to United States ports.

Wheat shipped from Fort William to Georgian Bay and Lake Huron ports is distributed:—

1st. To the millers in Ontario for home consumption and to grind in transit for export.

2nd. A very considerable quantity goes to the millers in Montreal and other parts of the province of Quebec, and the balance is for export.

A conservative estimate of the final destination of the wheat shipped from Fort William via the above mentioned ports places the amount exported to be about 60 per cent. Therefore, if we deduct 40 per cent for the requiremnts of Ontario and Quebec, there will leave 16,381,073 bushels as having been exported by Canadian routes in 1905 as against 11,218,882 via United States ports. Montreal Board of Trade returns for 1905 give the total amount of wheat exported via that port as 9,735,727 bushels, of which 9,297,950 bushels was Canadian wheat.

As already shown, Canadian vessels carried to Canadian ports in 1906, 27,924,428 bushels of wheat. Deduct 40 per cent for local consumption and milling in transit, leaves for export 16,754,657 bushels, as against 16,451,909 bushels via United States ports. (It is fair to assume that the entire shipments via United States ports are for export.) The total shipments from the Port of Montreal in 1906 were 14,298,251 bushels. In 1907 there were carried to Canadian ports, 32,827,280 bushels. After deducting 40 per cent for local consumption and milling in transit there is left a little over nineteen million bushels for export. The total shipments from the Port of Montreal including United States wheat were 20,975,373 bushels.

The total capacity of elevators and warehouses in western Canada operated for the season 1907-1908, including terminal elevators at the head of the Great Lakes, was about 58,535,700 bushels, of which 18,758,700 bushels were in terminal elevators.

The total increase in capacity for 1907-1908 was 3,313,500 bushels, namely: country elevators, 3,179,800 bushels; terminal elevators, 133,700 bushels. The total value was approximately, $11,707,000.

Statement showing shipments of wheat from Fort William and Port Arthur by vessel, and destination, during the seasons of navigation 1905, 1906 and 1907:—

Destination.	1905.		1906.		1907.	
	Canadian Vessels.	United States Vessels.	Canadian Vessels.	United States Vessels.	Canadian Vessels.	United States Vessels.
Owen Sound	2,535,338	....	1,817,688	....	2,017,698	....
Midland	2,417,468	....	3,527,309	....	3,685,541	....
Tiffin	....	....	....	....	581,657	....
Depot Harbour	9,067,510	....	5,246,208	....	5,677,280	....
Collingwood	489,788	....	6?0,618	....	389,240	....
Sarnia, Point Edward	2,251,069	....	2,665,382	....	2,474,728	....
Meaford	596,913	....	1,468,085	....	1,335,408	....
Goderich	2,010,634	....	1,431,824	....	3,819,606	....
Welland Canal	135,213	....	....	....	540,244	....
Port Stanley	....	....	125,200	....	....	....
Thorold	171,073	....	730,678	....	....	....
Kingston	1,003,772	....	....	....	....	....
Prescott	....	....	10,221,396	....	12,305,875	....
Montreal	6,623,010	....	....	....	....	....
Port Huron	1,757,976	181,793	1,086,595	386,514	369,510	555,938
Buffalo	454,963	10,493,823	2,729,209	10,806,530	3,889,722	8,797,964
Erie	212,183	543,266	238,102	1,133,653	360,182	219,3?2
Chicago	37,000	....	....	71,307	....	85,554
	40,982,792		44,376,338		47,105,539	

NOTE.—The discrepancy between shipments during the crop year and season of navigation is due to the fact that one is for twelve months and the other from April to December.

Assuming that 60 per cent of the quantities carried to Canadian ports and all the shipments destined to United States ports were for export, it will be seen that the shipments via United States channels are almost equal to those via Canadian ports at the present time.

Total capacity of elevators east of Lake Superior is about 18,455,000 bushels. Their location and capacity are as follows:—

—	Bushels.
Collingwood	160,000
Goderich (2)	700,000
Kingston (4)	1,600,000
Meaford (1)	750,000
Midland (1)	1,250,000
Owen Sound (2)	1,050,000
Point Edward (1)	500,000
Port Colborne (1)	800,000
Port Stanley (1)	25,000
Prescott (1)	1,000,000
Sarnia (1)	100,000
Tiffin (1)	800,000
Toronto (8)	1,620,000
Depot Harbour (1)	1,500,000
Coteau Landing (1)	500,000
Montreal (5)	3,000,000
Quebec (1)	1,000,000
St. John, N.B. (1)	500,000
West St. John (2)	1,000,000
Halifax (1)	500,000

Of recent years there have been annual complaints in regard to the congestion of the grain traffic at Lake Huron and Georgian Bay ports. Several complaints were made to the Board of Railway Commissioners, particularly in regard to a shortage of cars, and the inability of Ontario millers to get sufficient grain to continue operation. At a special session held in Montreal to consider these complaints the chief question under discussion was whether the railways were justified in giving export traffic preference over local freight, and if such discrimination which had admittedly taken local and milling in transit interests throughout Ontario.

Notwithstanding the efforts of the Grand Trunk to assist in relieving the situation, recognizing the national importance of export traffic, that road was unable to continue in the business steadily without sacrificing the local interests in Ontario.

The Ontario crop it is claimed is not nearly large enough for the home mills. The milling of Manitoba wheat has increased and it would seem as if a large portion of elevator space at Lake Huron and Georgian Bay ports were required for the local and milling in transit interests throughout Ontario.

RECEIPTS OF GRAIN AT MONTREAL.

—	By Rail.	By Canal.
	Tons.	Tons.
1902	263,861	242,225
1903	253,959	400,057
1904	154,625	220,076
1905	148,377	375,630
1906	386,963	449,673
1907	383,735	684,697

'By rail' includes Ontario and Quebec grain.

THROUGH GRAIN SHIPMENTS TO MONTREAL INTACT.

—	Number of Vessels.		Tons.
	Canadian.	American.	
1902	131	135	312,136
1903	56	18	99,582
1904	56	16	116,095
1905	96	18	180,206
1906	74	10	108,734
1907	102	14	168,796

The above statistics show the number of vessels which took cargoes through to Montreal intact.

Average for 19 years, 57·4 per cent carried by Canadian vessels.

Water lines carried grain to Montreal as follows:—

——	Year.	American Grain.	Canadian Grain.
		Bushels.	Bushels.
Montreal Transportation Company	1902	318,500	518,997
	1903	4,770,079	3,592,800
	1904	391,560	1,674,873
Montreal and Lake Superior Line	1902	137,000	760,029
Great Lakes Navigation Company	1903	216,000	....
	1904	1,444,214	144,551
Canadian Towage Company	1902	....	1,078,674
	1903	....	997,659
	1904	....	366,871

Railway lines carried grain to Montreal as follows:—

——	Year.	American Grain.	Canadian Grain.
		Bushels.	Bushels.
Grand Trunk Railway through Ontario	1902	1,012,000	5,788,000
	1903	742,930	4,797,964
	1904	....	2,792,072
Canadian Pacific Railway from all points	1902	1,404,765	....
	1903	1,200,000	....
	1904	1,192,705	....

A comparison of the east and west bound tonnage via St. Lawrence route between Lake Erie and Montreal shows the percentage of the west bound tonnage to be very small. In 1902 the east bound tonnage was 250,475 tons, west bound tonnage, 25,289 tons, the largest up to that date with two exceptions, namely, 1883 and 1889, in the series. The percentage of west bound traffic for twenty-one (21) years was .0492 per cent.

In 1903 the east bound tonnage was 390,786 tons, the west bound, 100,699. In 1904, east bound tonnage, 278,328 tons and the west bound 71,512 tons. In 1905 the east bound tonnage was 448,704 tons and the westbound, 72,482 tons. In 1906 the east bound was 554,231 tons and the west bound 96,791. In 1907 the east bound tonnage was 789,167, and the west bound 1,281 tons.

The statement has been made that the Welland canal has been of greater service to the United States than to Canadian traffic and any improvements in this direction will tend to increase this. The total quantity of freight eastward and westward through the Welland canal from United States ports to United States ports for twenty-one (21) years was: East bound, 5,352,149 tons, west bound, 4,218,237. The west bound tonnage almost equals the eact bound and goes to show the development in lake and rail traffic via the United States lines, that none of the Canadian lines, with the exception of the Canada Atlantic Transit Company, enjoy.

In 1903 there passed through the Welland canal 221,074 tons east bound and 149,151 tons west bound of through freight from United States ports to United States ports. In 1905 there were 190,547 tons east bound and 112,549 tons west bound. In 1907, 218,997 tons east bound and 177,660 tons west bound.

The total quantity of through freight passed through the whole length of the Welland canal during the season of 1907 was 1,604,321 tons. Of this quantity 1,214,544 tons were east bound and 387,777 west bound freight.

Of the east bound, Canadian vessels carried 593,384 tons, and United States vessels carried 621,160 tons, and of the west bound, Canadian vessels carried 143,436 tons and the United States vessels carried 246,321 tons, or a total of 736,840 tons for Canadian and 867,481 tons for United States vessels.

The quantity of grain and package freight carried by the Canada Atlantic Transit Company, which passed down the St. Lawrence canals from Coteau Landing to Montreal, will prove of special interest especially as this line has been of undoubted value to the shipping of the latter port. It will be noted that the tonnage carried went to increase the tonnage of the port, without in any way taking business away from existing lines.

— —	Grain.	Package Freight.
	Bush.	Tons.
1898	7,553,947	43,674
1899	9,287,980	50,042
1900	10,917,156	16,606
1901	10,759,606	29,719
1902	8,669,732	29,657
1903	10,103,859	19,542
1904	7,567,438	5,912

All of which was for export.

American grain included by this line for export, 1902, 5,996,617 bushels; 1903, 7,079,778; 1904, 2,246,593 bushels.

The Canada Atlantic Transit Company took the initiative in establishing a permanent lake and rail freight line from the head of the Great Lakes to the Canadian seaboard. By the inauguration of a regular fleet of steamers, this line has been in a position to divert a large export traffic to the port of Montreal thus assisting in the development of the policy to improve Canadian routes and divert traffic from United States channels. In order to do this they had to go into open market and carry grain at going rates, that is to say, at the rates that prevailed via Buffalo, build a transfer elevator at Coteau Landing and maintain a line of barges between that point and Montreal. As the lake rate of freight was fixed, no doubt, at times they were forced to carry grain east of Depot Harbour at an actual loss for the rail haul.

The Canadian Pacific and Grand Trunk railways at Owen Sound, Midland and and other Georgian bay ports have always reserved the right to refuse traffic offering which would be unprofitable for the rail haul, or when their equipment could be used to better advantage in other traffic, hence these latter ports have only been opened for export trade when business was offering that could be handled at a profit or when there was not sufficient other traffic in sight to employ their equipment.

STATISTICS OF THE PORT OF MONTREAL.

The following are some of the statistics of the Port of Montreal, giving details of trade via that port. In this connection it might be well to note the following in the review of general trade conditions for the year 1904:—'As compared with the United States ports the shipping business of the Port of Montreal was fairly satisfactory, but it was by no means a large and paying business or at all approaching what shipowners desire. The scarcity of export grain and the falling off in the cheese ship-

ments contributed to low freight rates and unprofitable business.' Further—' The export of wheat by Montreal during the past season has been the smallest for many years and was less than half the quantity exported in 1903. There have been many causes for this big decline. The chief cause has been the small crop of wheat grown in the United States, the prices in the American markets have, therefore, been much above the export value and for some months no American wheat has been shipped by Montreal.'

The Ontario crop is not nearly large enough for the home mills and the milling of Manitoba wheat in Ontario has increased very much and leaves the quantity for export from Manitoba less than we would usually have on a crop of from 50,000,000 to 55,000,000 bushels (estimated).

The above conditions have since changed somewhat.

The annual report of the Montreal Board of Trade for 1908 has the following:—

' The concluding paragraphs of the ' Foreword ' to the report on British and Continental ports by the President and Chief Engineer of the Montreal Harbour Commissioners are as follows:—

' Montreal has behind her a canal and river system 14 feet deep, tapping the trade of almost a whole continent. Equip in a proper manner her ocean and lake terminals and no force can divert from the cheapest and shortest trade route the business she ought to command.

' At the present rate of increase Canada will, during the 20th century, contribute to the empire a population exceeding that now occupying the British isles, and if she only cultivates one-quarter of her available wheat areas she will produce annually 800,000,000 bushels of grain.

' There are only two methods of handling this new business:—

(1) By increasing terminal facilities on Canadian soil.
(2) By allowing business to be taken care of through American ports.

' It would, therefore, seem to be a national duty to equip Canadian sea terminals in keeping with the railway and commercial growth of the country, in order to preserve the national prestige of handling Canadian business through Canadian seaports.'

'St. Lawrence route and the grain trade.—The popularity of the St. Lawrence route among grain exporters was made very evident last season, for, in addition to a large regular line traffic, twenty-five steamers took full cargoes of grain for Russia and for Mediterranean ports as far east as Greece.'

The tonnage visiting the Port of Montreal is increasing annually. During the season of 1905 it was the largest in the history of the port up to that time, being almost double the figures of 1895 and about half a million in excess of the average of the ten previous years.

Statement of vessels and tonnage at the Port of Montreal for seven years:—

——	1902.	1903.	1904.	1905.	1906.	1907.	1908.
Seagoing vessels	757	802	786	833	820	740	739
Tonnage of vessels	1,539,404	1,890,904	1,856,697	1,940,056	1,973,223	1,924,475	1,958,604
Number of inland vessels	9,358	15,338	10,063	11,112	12,557	....	....
Tonnage of vessels	1,875,668	2,415,791	2,354,975	2,785,551	3,095,174	....	....

Quantities of flour, wheat, corn and oats shipped from Montreal during a period of fourteen years:—This includes shipments for the lower St. Lawrence, Newfoundland and Trans-Atlantic ports.

—	Flour.	Wheat.	Corn.	Oats.
1895	1,646,768	3,651,311	2,613,638	13,719
1896	1,639,316	7,052,385	6,785,104	2,682,525
1897	1,397,103	9,924,029	9,924,364	5,231,903
1898	1,699,145	9,132,771	19,252,825	6,798,817
1899	1,903,152	9,909,159	13,276,350	3,991,164
1900	1,260,441	10,596,361	11,180,235	5,026,404
1901	1,500,399	13,626,071	4,088,642	2,667,116
1902	1,647,245	17,394,886	256,392	2,397,578
1903	2,174,607	16,055,004	6,884,724	1,138,261
1904	1,897,987	7,514,616	3,773,695	1,311,702
1905	755,439	9,954,348	5,901,128	2,683,767
1906	1,727,826	14,298,251	4,497,783	3,063,211
1907	1,738,411	20,975,373	5,012,647	4,133,032
1908	1,373,570	27,441,248	317,491	411,753

Exports of wheat, corn and oats from the Port of Montreal for thre years, distinguishing between home and foreign produce.

—	Wheat.	Corn.	Oats.
1906.			
Produce of Canada	12,893,431	Nil.	3,035,679
Foreign produce	949,155	4,521,599	663,820
1907.			
Produce of Canada	13,347,742	28	3,900,648
Foreign produce	4,774,267	4,745,042	....
1908.			
Produce of Canada	19,553,152	17,480	401,267
Foreign produce	10,908,195	430,829	109,130

The value of goods imported and exported into and from Canada via the St. Lawrence river, also the value of goods transhipped at Montreal for foreign countries both inwards and outwards for five years was as follows:—

—	Fiscal Year.				
	*1904.	1905.	1906.	†1907.	‡1908.
	$	$	$	$	$
Total imports from sea via St. Lawrence.	41,639,483	40,789,890	42,599,039	32,953,704	64,502,096
Total exports for sea via St. Lawrence...	74,198,438	66,358,205	86,857,711	66,046,556	95,656,910
Total merchandise received at Montreal for transhipment for foreign ports...	15,224,361	14,095,449	22,114,464	15,233,092	18,955,468
Total trade	131,062,282	121,243,544	151,571,214	114,233,352	179,114,474

* (NOTE.—1904 the highest up to that time since 1886.) † Nine months ending March 31. ‡ Ending March 31.

For the purposes of comparison the following statement of the value of merchandise imported into and exported from Canada through the United States from

and to foreign countries in accordance with Trade and Navigation returns is given.

	Value of merchandise imported from foreign countries through the United States.	Value of merchandise exported to foreign countries through the United States.
	$	$
Fiscal year, 1905	24,642,877	33,446,327
Fiscal year, 1906	25,936,120	40,787,902
Nine months ending March 31, 1907	22,056,142	34,069,739
Fiscal year ending March 31, 1908	27,431,412	39,610,766

It will be thus seen that Canadian imports and exports through the United States amounted to $58,089,204 in 1905; in 1906, $66,724,022; in 1907, $56,125,881, and in 1908, $67,042,178.

The largest percentage of this trade was undoubtedly through eastern United States Atlantic ports. During the same period the trade of the United States and other foreign countries of a similar nature to and from sea via the St. Lawrence, as already shown, amounted to $14,095,449 in 1905; $22,114,464 in 1906; $15,233,092 in 1907, and $18,955,468 in 1908.

The customs returns of the Port of Montreal show that about one-third of the total of exports and imports of Canada are entered at that port.

STATISTICS OF THE PRINCIPAL GRAIN CROPS OF THE NORTHWESTERN STATES, MANITOBA AND THE NORTHWEST PROVINCES TRIBUTARY TO THE GREAT LAKES.

The following are the statistics for 1905 of the principal grain crops of the Northwestern States, Manitoba and the Northwest Provinces tributary to the Great Lakes.

State.	Corn.	Wheat.	Oats.
	Bush.	Bush.	Bush.
Illinois	382,752,063	29,951,584	132,779,762
Wisconsin	55,407,849	7,893,381	98,579,988
Minnesota	49,997,455	72,434,234	80,669,700
Iowa	305,112,376	13,683,003	131,115,180
Kansas	193,275,836	77,001,104	23,248,223
Nebraska	263,551,772	48,002,603	58,474,370
South Dakota	51,614,739	44,133,481	28,103,517
North Dakota	2,458,638	75,623,014	46,194,381

The principal grain crops for 1907 were:—

State.	Corn.	Wheat.	Oats.
	Bush.	Bush.	Bush.
Illinois	342,756,000	40,104,000	101,675,000
Wisconsin	46,688,000	2,955,000	51,700,000
Minnesota	43,605,000	67,600,000	61,985,000
Iowa	270,220,000	7,653,000	108,900,000
Kansas	155,142,000	65,609,000	16,380,000
Nebraska	179,328,000	45,911,000	51,490,000
South Dakota	47,175,000	32,480,000	32,728,000
North Dakota	3,080,000	55,130,000	32,340,000

The crop of the Canadian Northwest for 1903-4-5-6-7 was as follows:—

		Wheat.	Oats.	Barley.
Manitoba	1903..	40,116,878	33,035,774	8,707,252
	1904..	39,162,458	36,289,979	11,177,970
	1905..	55,761,416	45,484,425	14,064,175
	1906..	61,250,413	50,692,977	17,532,553
	1907..	39,688,266	42,140,745	16,752,724
Northwest Territories	1903..	16,029,149	14,179,705	1,842,824
	1904..	16,875,537	16,332,551	2,205,434
Saskatchewan	1905..	26,107,286	19,213,055	893,396
Alberta	1905..	2,306,542	9,514,180	1,773,914
Saskatchewan	1906..	37,040,098	23,965,528	1,316,415
Alberta	1906..	3,966,020	13,136,913	2,157,957
Saskatchewan	1907..	27,691,601	23,324,903	1,350,265
Alberta	1907..	4,194,535	9,247,914	1,082,460

GRAIN TRAFFIC AMERICAN UPPER LAKE PORTS.

For statistics of Northwest crops see preceding paragraphs.

Throughout the past fifty years the Great Lakes have given the central West of the United States the opportunity to trade with the eastern part of that country because the Great Lakes occupy a midway position.

The principal ports on the Upper Lakes at which wheat, corn and oats are accumulated for shipment by the lake lines are Duluth, Superior, Green Bay, Manitowoc, Milwaukee and Chicago.

The points on the Lower Lakes to which shipments are made are Detroit, Toledo, Cleveland, Fairport, Erie, Buffalo, Oswego and Ogdensburg.

RECEIPTS OF GRAIN AT ABOVE PORTS.

1885—255,000,000 bushels.

1898—370,000,000 bushels, greatest ever received.

1903—269,000,000 bushels.

Vessel movements on the Great Lakes and domestic trade, during the fiscal year ending June, 1903, exceeded 75,000,000 tons net registry. The coastwise trade for the United Kingdom, Isle of Man, Channel Islands in 1903, was 58,369,517 tons. The coasting trade of Germany for 1902 is reported as 4,481,988 net registry, and the coastwise entrances of France for 1902 were 7,088,902 net tons. The grand total of these three nations would be approximately 70,000,000 tons, showing that the coastwise tonnage on the Great Lakes is even larger than that of these three nations combined.

COMPARATIVE SIZE OF VESSELS COASTWISE TRADE.

Great Lakes, 81,706 vessels, average tonnage 920 tons.

United Kingdom, 291,361 vessels, average tonnage 197 tons.

France, 81,027 vessels, average tonnage 87 tons.

The summary in the report of Internal Commerce of the United States for the year 1907 says:—' The vessel movement (U.S.) on the Great Lakes aggregated 73,769 vessels of 99,166,409 net tons register, compared with 76,097 vessels of 94,094,316 net tons register cleared during the preceding season.

The total traffic movement for the season aggregated 83,498,171 net tons compared with 75,609,648 net tons and 67,345,620 net tons shipped during the 1906 and 1905 seasons. The increase of eight million tons as compared with 1906 is due mainly to

the larger ore and coal movement, although the movement of grain and miscellaneous merchandise also show larger figures than a year ago.

The iron ore shipments by lake for the year, exclusive of about 275,000 gross tons exported to Canada, were 40,727,972 gross tons. The largest shipping ports in the order of their importance were Duluth, Two Harbours, Superior, West Superior, Escanaba, Ashland, Marquette and Presque Isle.

The greater part of the ore was received at the Lake Erie ports of Ashtabula, Cleveland, Conneaut, Buffalo and North Tonawanda, Lorain, Fairport, Erie, Toledo, Huron and Sandusky. Some is credited to Chicago, Indiana Harbour, Milwaukee and Detroit.

The eastward grain movement for the season included 63,349,585 bushels of wheat compared with 47,726,778 bushels shipped during the 1906 season, the main shipping ports in the order of their importance being Duluth, Superior and Chicago, which are credited in the aggregate with over 93 per cent of the total wheat shipments by lake. The corn shipments, 44,355,990 bushels, about 91 per cent of which shipments for the season originated in Chicago, were somewhat larger than the 1906 shipments of 43,531,540 bushels. The shipments of oats, 20,680,188 bushels, mainly from Manitowoc, Milwaukee and Chicago, were 38 per cent below the 1906 total, while the barley shipments, 13,564,074 bushels, mainly from Superior and Milwaukee, show a 26 per cent decrease as compared with the 1906 figures. The importance of Buffalo as a receiving port for grains shipped from the upper lakes is seen from the fact that 87 per cent of all the wheat, 64 per cent of all the corn, 52 per cent of all the oats and 83 per cent of all the barley received by lake is credited to that port.

The flour shipments from Duluth, Superior, Chicago and Milwaukee mainly 1,314,987 net tons (of ten barrels each) were slightly below the shipments reported for the preceding season, and were directed chiefly to Buffalo, and to a smaller extent to other Lake Erie ports.

The lumber shipments for the season, 1,380,284 M. feet show a considerable decrease compared with the total of the preceding year, 1,807,570 M. feet.

The west bound traffic was made up largely of soft coal shipments from Lake Erie ports to the upper lake ports, the principal shipping ports in the order of their importance being: Toledo, Cleveland, Ashtabula, Lorain and Huron, the aggregate shipments from these five ports constituting over 75 per cent of the total shipments, 15,428,309 net tons. The hard coal shipments for the year, 4,079,177 net tons proceeded mainly from Buffala, though considerable shipments of this article are also credited to Erie and Oswego. The destination of these shipments were largely the head of the lakes, Chicago and Milwaukee.'

Iron ore trade.—The largest item in lake traffic is iron ore, which is delivered along a line of 1,000 miles, dotted with manufacturing towns. This has cheapened iron and steel below the cost in any other part of the world. The development of this industry accounts for 80 per cent of the Great Lakes trade, (see diagram, page 400), has necessitated alone, the enlargement of harbours, channels and docks and the creation of ship yards.

The United States Deep Waterways Commission, 1901, stated: 'The amount expended in deepening and widening channels is about $12,000,000, and marine history contains no parallel to the rapid development which has been made possible by this assistance.'

The following are the statistics of the principal lake ports:—

Buffalo.—The total amount expended by the United States on the improvement of Buffalo harbour to June 30, 1907, was $5,129,013.70. The maximum draft that could be carried June 30, 1907, at mean level over the shoalest part was twenty feet.

The new breakwater has given the city a magnificent outer harbour, and one result has been an expenditure of upwards of $50,000,000 in two steel plants. The grain trade has for years been the important factor in the growth and development of Buffalo. The growth of freight receipts and shipments, without a corresponding increase in railway facilities, caused serious congestion in 1905. The lines east were unable to forward their freight, and as a result vessels sailed from New York without cargo. Every effort is being made towards further improvement of this harbour.

WHEAT RECEIPTS AT BUFFALO, 1904.

From	Bushels.	Tons.
Chicago	5,324,265	160,000
Duluth and Superior	15,182,215	460,000
Milwaukee	303,000	9,200
Green Bay	22,000	700
Washburn	223,000	6,700
Gladstone	247,500	7.500
Toledo	488,000	14,800
Fort William	3,979,909	120,600
Port Arthur	500,111	15,100
Total	26,270,000	794,600

Besides this 75 million bushels of other grain and 1 million barrels of flour arrived.

It will be noted that Fort William and Port Arthur contributed 4,480,000 bushels. Duluth and Superior probably shipped some Canadian grain brought there by United States lines from the Canadian northwest.

Buffalo has twenty-eight elevators, with a total storage capacity of 24,190,000 bushels. The transfer capacity of these elevators for each twenty-four hours would probably aggregate 5,500,000 bushels; that is to say, there are facilities for receiving from lake vessels and railroads and transferring to canal boats and cars daily the quantity named.

In 1905, Buffalo handled 10,201,100 barrels of flour and 126,465,729 bushels of grain, of the latter 40,436,616 bushels was wheat. Of this Fort William and Port Arthur contributed 11,778,788 bushels. The figures of 1904 are below the average due to the strike of the Masters and Pilots Association.

In 1907, Buffalo received 9,759,676 barrels of flour and 132,438,798 bushels of of which 66,658,138 bushels was wheat Of this Fort William and Port Arthur contributed 12,643,395 bushels.

Buffalo reports arrivals and departures of vessels for the seasons of navigation, 1905 and 1907.

——	Number of Vessels.	Tonnage.
Arrivals.		
1905—Vessels in coastwise trade entered	3,103	5,586,374
American vessels entered from foreign ports	842	465,031
Foreign vessels entered from foreign ports	142	23,170
1907—Vessels in coastwise trade entered	3,075	6,687,941
American vessels entered from foreign ports	934	518,833
Foreign vessels entered from foreign ports	150	81,056
Departures.		
1905—Vessels in coastwise trade entered	3,180	5,708,296
American vessels cleared for foreign ports	847	423,557
Foreign vessels cleared	134	14,775
1907—Vessels in coastwise trade cleared	3,191	6,921,190
American vessels cleared for foreign ports	873	413,687
Foreign vessels cleared	130	36,535

It will be noted that foreign arrivals from foreign ports equalled only about 14 per cent and departures for foreign ports a little over 13 per cent of the total in 1905.

The principal receipts by lake and river were wheat, corn, flour, oats, iron ore, lumber, copper, pig iron, glucose, lard and pork. The shipments by lake were principally coal, sugar, salt and cement and aggregated 4,318,281 tons in 1905, and 4,888,142 tons in 1907.

Duluth.—The combined elevator capacity of Duluth and Superior is 46,775,000 bushels.

WHEAT RECEIPTS AT DULUTH.

—	Bushels.
1902	42,406,900
1904	26,635,200
1905	31,186,700
1906	41,558,151
1907	55,299,825

WHEAT SHIPMENTS FROM DULUTH.

—	Bushels.
1902	44,116,600
1904	21,400,100
1905	28,126,600
1906	39,152,541
1907	49,207,734

WHEAT SHIPMENTS FROM WEST SUPERIOR.

—	Bushels.
1902	23,889,200
1904	12,171,100
1905	12,580,000
1906	19,518,332
1907	21,165,783

Shipments of grain and flax seed from Duluth aggregated 58 million bushels in 1905, and there was stored over that winter nearly 12,000,000 bushels, in 1906, 83,623,243 bushels and in 1907, 81,525,509 bushels.

PRODUCTION OF FLOUR AT DULUTH.

—	Barrels.
1899	1,763,900
1900	345,460
1901	860,600
1902	1,809,600
1903	1,178,700
1904	835,700
1905	793,100
1906	908,175
1907	715,280

Chicago.—The shipments of flour and grain from Chicago, through Canadian ports for the year 1905, were as follows:—

Port.	Flour.	Corn.	Wheat.	Oats.	Barley.
Depot Harbour	32,777	3,710,087	108,000	1,893,800	46,000
Montreal	....	2,830,474	48,000	584,327	49,913
Midland	....	1,701,750	....	483,837	....
Collingwood	....	1,399,715	....	101,330	....
Kingston	....	205,225	....	326,425	80,000
Sarnia	....	....	....	929,460	....
To other Canadian ports	....	639,311	....	2,367,054	....

In transit shipments by lake from Chicago to Canadian ports, thence by rail to New England points (carried in United States bottoms only) flour, 1,650 tons; wheat, 108,000 bushels; corn, 6,780,047 bushels; oats, 4,415,210 bushels, rye, 60,000; barley, 46,000; millstuffs, 13,897 tons; oil-cake, 170 tons; unclassified, 369 tons.

In transit shipments for 1907 were flour, 18,080 barrels; wheat, 929,401 bushels; corn, 5,938,062 bushels; oats, 649,652 bushels; millstuffs, 21,725 tons; oil-cake, 203 tons; malt, 78 bushels; corn and oatmeal, 328 bushels; oil, 120 barrels; merchandise unclassified, 128 tons.

There were 1,048,200 bushels of wheat and 5,432,505 bushels of oats exported by lake in 1907, a part of which, no doubt, went by Canadian routes.

The monthly report of Internal Commerce, United States, in dealing with the lake in transit movement of merchandise, 1906-7, says: 'The table presenting the annual figures of the movement of freight in bond destined to or shipped from domestic ports on the Great Lakes, but passing through Canadian territory in order to reach its destination shows the shipments to be considerably in excess of the receipts. This is due largely to the fact that eastbound bonded grain shipments from Chicago are relatively heavy. The tonnage enters Canada at points on Georgian Bay, is transferred to the Grand Trunk railway, and again enters the United States at northern New York and Vermont points.

There were received at the United States lake ports from these sources, 50,828 net tons of freight in 1907, as against 47,885 net tons in 1906. Shipments from these ports through Canadian territory amounted to 234,839 net tons in 1907 as compared with 299,433 net tons in 1906.

The receipts required 151 entrances of vessels, the total registered tonnage of which was 291,872 net tons, while the shipments were made in 312 vessels of 466,401 net tons. During 1906 there arrived in this trade 177 vessels of 306,117 net registered tons and 490 vessels cleared, having a registered tonnage of 641,093 net tons.

While the figures of the lake-in-transit movement are included in those found in the tables representing the domestic commerce on the Great Lakes, they are believed to contain enough individual significance to deserve a separate tabulation."

From this it will be seen that almost the entire tonnage from the District of Chicago to Canadian lake ports, whether for export via the Port of Montreal, or for New England, was carried in United States bottoms. Outside Depot Harbour, Kingston and Montreal the bulk of the traffic via the other ports was for New England points, therefore, did not add to the export trade via the Canadian seaboard.

The tonnage of the District of Chicago for 1905 and 1907 was as follows:—

—	Number of Vessels.	Tonnage.
Arrivals.		
1905—Coastwise trade	7,092	7,190,000
Foreign trade	144	174,096
1907—Coastwise trade	6,267	7,649,362
Foreign trade	131	174,133
Clearances.		
1905—Coastwise trade	7,007	7,056,886
Foreign trade	261	316,077
1907—Coastwise trade	6,182	7,513,303
Foreign trade	256	312,237

Receipt of flour and grain at principal lake ports during the last eight years:

	Bushels.
1900—Chicago	349,637,295
Milwaukee	54,602,942
Duluth	61,060,435
1901—Chicago	291,252,936
Milwaukee	51,847,150
Duluth	78,751,746
1902—Chicago	218,815,806
Milwaukee	49,462,477
Duluth	81,092,758
1903—Chicago	275,468,195
Milwaukee	53,054,282
Duluth	62,619,477
1904—Chicago	265,496,477
Milwaukee	47,765,282
Duluth	59,190,289
1905—Chicago	296,428,100
Milwaukee	49,073,935
Duluth	70,811,351
1906—Chicago	280,832,206
Milwaukee	56,774,956
Duluth	85,430,558
1907—Chicago	307,246,141
Milwaukee	59,825,817
Duluth	84,549,599

The total receipts at the following principal lake and river ports, namely—St. Louis, Peoria, Chicago, Milwaukee, Duluth, Detroit, Toledo, Minneapolis, Omaha and Kansas City were 1906, 818,590,308 bushels, and 1907, 860,098,015 bushels.

COMMERCE OF CANALS AT SAULT STE. MARIE.

In 1870 the average tonnage of vessels on the lakes was 175 tons; in 1877, 440 tons; in 1880, a thousand ton vessel was a rarity. Lake vessels are now built to carry 5,000 tons on a 16-foot draft, and 7,000 to 10,000 tons on a 20-foot draft. In 1905 there were 10 steamers of 10,000 net tons; 7 over 11,000 net tons, and 3 over 12,000 net tons engaged in the carrying of trade through the canals. The steamer E. H. Gary carried a cargo of 12,368 net tons. The maximum traffic for a single day was 300,752 freight tons on 148 vessels, having an aggregate registered tonnage of 233,429 tons.

It was the development of iron mines which furnished the trade for the large steamships, also the material for constructing them, while the use of the larger and better ships have lowered freight rates and still further developed the iron industry.

With the carriage of ore downwards towards Pennsylvania came a movement of coal up the lakes. Ore and coal is a highly specialized traffic and constitutes 80 per cent of the whole lake business (see diagram, page 400.)

The canals have aided the wheat production in the country west of Lake Superior. Their influence can also be traced in the development of the lumber traffic. During 1906 the principal freights passing the canals were:—

		U. S. Canals.	Canadian Canal.	Total.
Eastbound.				
Wheat	Bush.	49,977,831	34,293,527	84,271,358
Other grain	"	37,661,898	16,674,508	54,336,406
Flour	Brls.	4,091,300	2,393,454	6,484,754
Iron ore	Tons.	32,453,645	2,903,397	35,357,042
Westbound.				
Coal (hard)	Tons.	872,383	138,992	1,011,375
Coal (soft)	"	6,634,006	1,094,249	7,728,255
Salt	"	371,680	96,482	468,162
General merchandise	"	482,501	501,764	984,265

TOTAL FREIGHT, 1906.

Eastbound	41,584,905
Westbound	10,166,175
Total	51,751,060

The freight through the Canadian canal was 13 per cent of the total freight, or 6,570,788 tons, an increase of 20 per cent over the figures for 1905.

The Canadian canal opened April 14, closed December 22, 1906.

The total freight tonnage for 1907 stands at 58,217,214 net tons, of which 45,544,319 net tons was east bound, and 12,672,895 tons westbound. Of the total freight moved 39,594,944 net tons or 87 per cent of the total eastward movement was represented by iron ore.

GRAIN RATES TO SEA.

The reduction of rates on the grain traffic of the Great Lakes is interesting. Chicago rates are given as they are the recognized basis. In 1863 the average rate on wheat per bushel, Chicago to New York, by lake and canal was 22·91 cents per bushel.

In 1904 the rate on wheat was, lake and canal, 4·71; lake and rail, 5·02, and by all rail, 11:12 cents per bushel. The latter rate was for domestic consumption.

The rates for 1905, 1906 and 1907 were:—

—	Lake and Canal.	Lake and Rail.	All Rail.
1905	5·51	6·29	10·2
1906	5·94	6·40	10·5
1907	6·68	6·97	11·3

cents per bushel.

For domestic consumption, local rate for export only, when consigned or delivered steamer, 9·70 cents.

The rate on grain from New York to Liverpool was in 1881 4⅛ pence; in 1883, 4 5/16 pence; in 1902 and 1903, 1 7/16; in 1904, 1⅛ pence; in 1905, 1⅝ pence; in 1906, 1 7/16 pence; and in 1907, 1¾ pence per bushel.

The average rate on grain, flour and provisions, Chicago to Liverpool for 1904, was 20·19 cents per hundred pounds; 1905, 19·16 cents; 1906, 18·75 cents, and 1907, 19·22 cents.

Existing routes to Montreal, either all water or lake and rail, have not until recently had any marked influence on rates to the seaboard; therefore, the rates that prevailed via Buffalo are used for the purpose of comparison.

The average rate on wheat per bushel via canal from Buffalo to New York for ten years to 1904 was 3·15 cents per bushel. In 1904 the average for the season was 3·2 cents; 1905, 3·9 cents, 1906, 4¼ cents and in 1907, 5 cents per bushel.

The rail rate on wheat in 1896 from Buffalo to New York was 3·4 cents per bushel. This was however advanced to 4 cents in 1904.

The average lake rate on wheat for years given from Chicago and Duluth to Buffalo was:—

——	From Chicago.	From Duluth.
	Cents.	Cents.
1900, average for the season	1·8	....
1901 " "	1·42	2·3
1902 " "	1·51	1·9
1903 " "	1·41	1·6
1904 " "	1·32	1·8
1905 " "	1·67	2·31
1906 " "	1·72	2·19
1907 " "	1·57	1·86

Average through rate from the head of the lakes to the seaboard for five years, 1900 to 1904 inclusive, 4·71 cents per bushel. This average is probably the lowest in the history of lake and canal traffic.

The above rate is exclusive of handling charges at Buffalo. To this must be added the cost of:—

	Mills per bushel.
Ruling rate elevating and 10 days storage	5·0
Canal boat trimming	1·5
Receiving, weighing and discharging New York	6·25
Ocean vessel trimming	2·0
Floating elevator	5·0

Making the cost of handling at Buffalo and New York 2 cents per bushel, lakes to sea, 4·71, and handling Buffalo and New York, 2 cents, total, 6·71 cents.

As to the grain trade of the Canadian northwest, the average rate on wheat, lake and rail, has been from 7 to 8 cents per bushel from the elevator at the head of the lakes to vessel at the seaboard. The average rate for 1905, was, no doubt, somewhat higher than this, as very little, if any, grain was carried from Fort William to Georgian Bay and Lake Huron ports at less than 2½ cents per bushel, in fact charters were made as high as 6 cents per bushel with no accommodation east of the lakes to take care of the business.

The average published minimum rate, all water, Fort William and Port Arthur for 1906 was 6⅝ cents per bushel, including insurance; 1907, 6⅝ cents, exclusive of insurance. In 1908 the rate at the opening of navigation was 7 cents, early in May this was reduced to 5½ cents, on May 20, it was further reduced to 4½ cents, since which date no rates have been published.

A comparison of the rates is only necessary to show to what extent the Northwest is discriminated against.

Not only will a deep waterway control and determine the rates of transportation on the products of the northwest but it will make possible the further development of our coal industries in the east and of our iron and other mineral resources, lumber, timber, pulpwood, &c., in the interior, so that vessels carrying cargo from the head of the lakes to the seaboard would secure return loads, thus reducing the cost of transportation to a minimum as shown.

The following are the rates on wheat from some of the principal wheat stations in Manitoba, Alberta and Saskatchewan to Fort William:—

From.	Distance.	Rate per Bushel.	Rate per ton per Mile.
	Miles.	Cents.	Cents.
Winnipeg	427	6·0	·468
Portage la Prairie	483	7·2	·498
Elkhorn	624	9·0	·480
Broadview	692	9·6	·462
Qu'Appelle	752	10·2	·452
Moosejaw	826	10·8	·437
Swift Current	937	12·0	·431
Medicine Hat	1,087	13·2	·404
Calgary	1,267	14·4	·379

To arrive at Montreal all rail rate add 12 cents per bushel.

The lake and rail rate published for 1905 on wheat, Fort William to Montreal, 8·1 cents per bushel; to West St. John, Portland, Boston, 13·5 cents per bushel. In 1908 the rate to Montreal was 8·7 cents per bushel including terminals; to West St. John, Portland and Boston 9·3 cents.

The all rail rate Winnipeg to Montreal is 18 cents per bushel; from Calgary 26·4 cents per bushel.

GRAIN BY RAIL.

Very little of the grain of the Northwest finds its way to the East all rail. Wheat billed to points in the East by the all-rail route from Winnipeg and other points in the West for eight years.

Year.	Bushels.	Year.	Bushels.
1900	253,150	1904	1,644,000
1901	1,327,710	1905	1,523,500
1902	552,300	1906	1,448,928
1903	60,060	1907	721,180

Assuming the rate of 6 cents per bushel Fort William to Montreal (lake and rail) is divided 2½ cents to the steamer and 3½ cents for the rail haul, the earnings say Depot Harbour to Montreal, 381 miles would be ·0306 cents per ton per mile.

EXPORTS FROM UNITED STATES SEAPORTS.

In order to show to what extent the combined flour and grain trade has contributed to the receipts of traffic at leading seaboard markets, a table has been com-

piled representing receipts at Portland, Boston, New York, Philadelphia, Baltimore, Newport News, Norfolk, including Portsmouth, on the Atlantic seaboard, New Orleans and Galveston on the gulf coast. Averages of annual receipts for eight-year periods are given. From these averages it appears that each and all of the Atlantic seaboard cities have increased their average receipts from period to period as follows: From 1880 to 1887, inclusive, the annual receipts averaged 230,483,683 bushels; from 1880 to 1895 inclusive, 248,731,912 bushels and from 1896 to 1903, inclusive, 370,053,052 bushels.

The two leading gulf ports received for the first period 15,897,148 bushels per annum of the average; for the second 20,904,463 bushels, and for the third, 52,329,-030 bushels. The combined receipts of the Atlantic seaboard and the gulf ports mentioned show a similar progression.

Exports of grain and flour by way of the four national borders, given on this page, in grain exports withdrew from the domestic supply are slightly more than 200,-000,000 bushels in the fiscal years 1902-03. The last fiscal year, however, shows only 112,079,789 bushels of grain sent to foreign markets. This shrinkage is one of the most remarkable features, not only in the year's trade just closed, but in the history of the grain trade of the United States.

For the fiscal year ending June 30, 1902, 17,509,266 barrels of flour were shipped out of the country. The next year 19,448,357 barrels were spared from the domestic demand, and in the year ending June 30, 1904, 12,753,644 barrels.

The direction which these commodities took in passing out of the internal commerce of the country into the foreign trade is shown by the following table:—

Outward movement of export flour and grain by coasts, during twelve months, 1902-3.

—	Flour.	Grain.
	Barrels.	Bushels.
Atlantic ports	13,413,067	97,573,207
Gulf ports	1,692,763	53,575,[illegible]01
Pacific ports	3,688,601	34,502,238
Northern border ports and other principal ports	653,926	18,036,254

The following is a comparative table of receipts of grain, including flour and meal, reduced to bushels at six seaboard markets during the years 1904, 1905, 1906, and 1907. These totals serve to show the relative share of each port in this branch of domestic trade.

—	1904.	1905.	1906.	1907.
Boston	16,232,855	32,400,096	35,055,953	37,775,891
New York	61,112,185	118,329,466	114,832,739	118,245,465
Philadelphia	14,811,731	34,701,676	42,943,076	51,586,426
Baltimore	18,215,220	42,225,056	52,368,809	51,228,653
New Orleans	8,753,247	31,007,764	33,653,354	21,444,681
San Francisco	15,721,179	21,663,250	15,851,420	15,840,784
	134,846,417	280,327,308	294,705,351	296,121,901

The exports of domestic wheat for the following years from the principal United States Eastern Atlantic ports were as follows:—

Year.	Bushels.
New York—	
1903	15,181,840
1904	1,750,628
1905	6,406,393
1906	19,568,284
1907	27,111,717
Boston—	
1903	2,867,994
1904	156,164
1905	119,677
1906	1,983,993
1907	4,360,382
Portland.—	
1903	1,718,855
1904	119,749
1905	717,070
1906	742,386
1907	1,613,476
Philadelphia—	
1903	1,600,700
1904	8,000
1905	640,448
1906	4,749,586
1907	11,295,013

NOTE.—The wheat receipts at Boston, New York, Philadelphia and Baltimore for the year 1907 amount to 77,398,094 bushels as compared with 55,731,795 bushels during 1906. The forty percent increase in receipts in 1907 correspond with a corresponding increase of forty-three per cent in the exports from these ports, leaving practically the same amount for local consumption. Flour receipts were 16,144,919 barrels, compared with 14,268,928 in 1906.

Year.	Bushels.
Montreal (export of wheat)—	
1903	16,055,004
1904	7,514,616
1905	9,735,727
1906	14,298,251
1907	20,975,373
1908	27,441,248

The above figures do not include the quantities of Canadian breadstuffs in transit exported via leading United States ports. During 1904 they were as follows:—

——		Baltimore.	New York.	Portland.	Boston.	Philadelphia.
Flour	Brls.	9,348	313,851	106,149	75,407	5,034
Wheat	Bush.	110,991	1,531,189	3,528,977	2,286,571	248,000
Corn	"	9,986	....	....	....	2,424
Oats	"	72,672	1,126,859	590,301	91,029	300,637
Rye	"	8,469	4,204	4,720	....	....
Barley	"	....	395,112	353,850	49,458	....
Buckwheat	"	....	234,448	14,649	10,172	....
Total grain in bushels		192,132	3,301,714	4,492,497	2,437,230	551,061

Total flour in barrels	509,789
Total grain in bushels	10,974,634

During 1905 Canadian breadstuffs shipped by these ports were flour, 428,000 brls.; grain of all kinds, 12,119,637 bushels, of which 10,795,346 bushels was wheat.

During 1906 actual shipments of Canadian breadstuffs in transit for export were: Flour, 526,849 barrels; grain of all kinds, 24,159,284 bushels, of which 22,150,640 bushels was wheat, distributed as follows: Via New York, 305,861 barrels flour, 4,877,387 bushels of wheat, 1,368,745 bushels other kinds of grain; via Portland, 127,446 barrels of flour, 6,289,461 bushels of wheat, 550,669 bushels other kinds of grain; via Boston, 68,911 barrels flour, 9,216,085 bushels wheat, 86,946 bushels other kinds of grain; via Philadelphia, 23,229 barrels flour, 960,436 bushels of wheat, 2,284 bushels of other kinds of grain, and via Baltimore, 1,422 barrels flour, 807,271 bushels of wheat.

During 1907 the shipments were: Flour, 486,016 barrels grain of all kinds, 23,963,116 bushels, of which 20,981,626 bushels were wheat, viz.: Via New York, 232,428 barrels flour, 4,868,882 bushels of wheat, 2,422,954 bushels of other kinds of grain; via Portland, 108,951 barrels of flour, 4,762,353 bushels of wheat, 378,360 bushels other kinds grain; via Boston, 97,074 barrels flour, 8,151,394 bushels wheat, 161,986 bushels other kinds grain; via Philadelphia, 44,628 barrels flour, 3,114,373 bushels wheat, 17,523 bushels other kinds grain; via Baltimore, 2,935 barrels flour, 84,624 bushels wheat.

The United States Bureau of Statistics, Department of Commerce and Labour, report the value of Canadian trade handled through American ports during 1904 as being $96,000,000. This statement, however, is at variance with the figures given in the Canadian Year Book:—

Value of merchandise imported from foreign countries through the United States.	$25,162,379 00
Value of merchandise exported to foreign countries through the United States.	$37,799,987 00

See statement for 1905, 1906, 1907 and 1908, page 567.

The following statistics show to what extent the gulf ports are bidding for the grain of the Northwest:—

—	Exports Wheat and Corn, 1903, 1904, 1905, 1906 and 1907.	
	Wheat.	Corn.
	Bushels.	Bushels.
New Orleans—		
1903	13,566,000	13,828,000
1904	2,603,000	5,111,000
1905	587,000	20,410,000
1906	5,731,000	18,388,000
1907	5,336,000	7,550,000
Norfolk and Newport News—		
1903	372,000	4,541,000
1904	11,000	1,770,000
1905	96,000	4,315,000
1906	797,000	4,344,000
1907	368,000	1,597,000
Galveston—		
1903	18,710,000	4,541,000
1904	3,456,000	3,408,000
1905	2,614,000	10,278,000
1906	11,553,000	10,332,000
1907	9,561,000	6,609,000
Other ports, including Charleson, Pensacola and Mobile—		
1903	1,174,000	171,000
1904	768,000	478,000
1905	48,000	810,000
1906	410,000	1,154,000
1907	414,000	1,127,000

Extract from Bulletin (United States Department of Agriculture), on European grain trade,—

Grain Deficit in western Europe.

'Plentiful supplies of grain from newer countries possessing vast areas suited to cereal production have caused western Europe to depend for a part of its needs on foreign sources. The grain deficit of western Europe during the five years 1901-1905 averaged almost half a billion bushels of wheat, 200 million bushels of corn, 150 million bushels of barley, 144 million bushels of oats, and 78 million bushels of rye. Wheat is pre-eminently the international grain, while of the five other important cereals, rye enters least into foreign trade. Grain is imported into western Europe to some extent from Russia and the Balkan states, but principally from countries outside of Europe.

The chief importing country, the United Kingdom, obtains nearly 80 per cent of its wheat supply, all of its corn, more than half of its limited requirements of rye, 45 per cent of its barley and 25 per cent of its oats from foreign and colonial sources. Especially in the case of wheat the dependence on imported grain shows a marked increase. As late as 1871-75 slightly more than half the total supply was raised within the United Kingdom. Accepting in the absence of official statistics of production the estimates quoted in the report of the British Tariff Commission, fifteen years later in 1886-1890 the average contribution of British agriculture had fallen to 35 per cent of the wheat supply and in 1901-1905 to only 21 per cent.

During the period covered by the bulletin, 1883-1905, Germany has taken rank as the largest importer of wheat, except the United Kingdom.

The increased dependence on foreign grain, exemplified by the United Kindom and Germany, is general throughout the northwest or Teutonic portion of Europe, comprising the countries north of France and Italy and west of Russia, Hungary and the Balkan Peninsula.

The European surplus producing countries are all situated in eastern Europe. Russia with its vast area exports by far the largest quantities of grain, averaging in 1901-1905 no less than 141 million bushels of wheat a year, 93 million bushels of barley, 86 million bushels of oats, 60 million bushels of rye and nearly 23 million bushels of corn. Russia's exports represent about 24 per cent of its wheat crop, 7 per cent of its rye, 10 per cent of its oats and 29 per cent of its barley..

The great importance of the United Kingdom as a market for the surplus grain of other countries may be measured by the following: Taking account of both wheat and wheat flour, the imports from foreign countries have increased much less rapidly of late years than those from British possessions. In 1883 foreign countries contributed in both grain and flour the equivalent of 131,000,000 bushels of wheat, while in 1906 they contributed 145,000,000 bushels. This comparison, however, under-estimated the importance of the foreign countries in the supply of the British market prior to 1904, for the percentage supplied from foreign sources in 1906 was far below the average for 1883-1903. The contribution from British possessions has increased remarkably from 31,000,000 bushels in 1883 to 80,000,000 in 1905 and 65,000,000 in 1906. Imports from Russia have varied greatly in amount, the highest being 46,000,000 in 1905 and the lowest 5,000,000 bushels in 1899 and 1901. From Canada the imports have shown a constant increase, while from the United States an apparently large decrease is observed from 1901 to 1905.

The returns, however, show that a much larger supply of wheat and wheat flour was imported from the United States than during 1904 and 1905 when the supply available for importation from the United States was comparatively small.

The imports of wheat into the United Kingdom were in 1900, 128,183,048 bushels; 1901, 130,122,589; 1902, 151,204,157; 1903, 164,511,256; 1904, 182,527,333; 1905,

182,229,131; 1906, 173,538,773; of wheat flour—1900,12,313,218. 1901, 12,900,817; 1902, 11,077,909; 1903, 11,772,256; 1904, 8,413,082; 1905, 6,831,293; 1906, 8,108,743 barrels.'

Of these importations Canada is given credit for the following:—

——	Wheat.	Wheat Flour.
	Bushels.	Barrels.
1900	11,830,187	682,482
1901	12,491,192	776,057
1902	17,784,620	1,110,407
1903	20,163,970	1,507,210
1904	11,564,560	1,169,010
1905	12,174,456	760,057
1906	21,111,440	1,034,571

Ten years ago Liverpool looked to the United States for 70 per cent of its supply of grain. This has shrunk appreciably. In 1903 the imports fro mthe United States were—wheat 27 per cent, corn 37 per cent, barley 9 per cent, oats 4 per cent. Flour has not dropped to any extent, about 5 per cent in ten years.

The average freight rate from principal points to Liverpool 1902-3, in shillings sterling per ton was:—From New York, 4s. 11d.; Odessa, 8s. 3d.; Bombay, 13s. 1d.; River Platte (down river), 13s. 9d.; Montreal rates are on a parity with New York. Rates are practically the same to-day.

TRAFFIC POSSIBILITIES.

The brief review of the upper lake trade given herein shows that 80 per cent of it, consisting of ore and coal is between Duluth and Lake Erie and cannot be diverted to any other route. There is, however, a grain trade part of which may be diverted by a deep water route to Montreal. If deposits of high class easily mined iron ore were discovered along the Ottawa route, then a large traffic would soon spring up between it and eastern province coal.

The facilities for manufacture along the line of the waterway are very striking and deserve special consideration as immense water powers will be available.

The discovery in the states of Michigan and Minnesota of easily worked high-class ores in unprecedented quantities and the cheap transportation by water to the coal and coke at Pittsburg made a tremendous development possible.

The Minnesota iron ranges have been traced northward and at various points in Canada give promise of containing valuable bodies of ore. When it will be possible to utilize iron ores, which are now below the accepted standard, numerous deposits in eastern and western Ontario will be available.

In the province of Quebec there are large and valuable deposits of magnetic ore contagious to the line of the waterway. One of the most valuable deposits of magnetic ore is near Hull, opposite Ottawa, an ore assaying from 64 to 68 per cent of metallic ore.

The annual consumption of iron and steel and their products in Canada is between 800,000 and 900,000 tons. The production of pig iron in the Dominion

amounted to 278,219 tons in 1904. The consumption of pig iron in Canada in 1904, was as follows:—

—	Tons.
Made from foreign ore	226,989
Made from Canadian ore	46,445
Imports	73,900
Total consumption	347,334

The value of the exports of iron and steel goods manufactured in Canada in 1904 amounted to $1,991,821, the value of the imports of iron and steel and manufactures of same into Canada for 1904 was $41,152,789.

Total imports of iron and steel and manufactures of same during the fiscal year:—

Year.	Imports.
	$ cts.
1905	33,475,278 00
1906	38,545,539 00
1907	38,721,015 00
1908	52,000,206 00

The import of iron and steel is divided as follows:—

1st. Interchangable mechanism, the manufacture of which requires the highest skill and workmanship; 2nd, hardware, cutlery and edge tools; 3rd, machinery; 4th, castings and forgings, rails, and railway supplies and other forms of iron, steel, pig iron, &c. Of these the United States supply the following per cent:—

—	Per cent.
Interchangeable mechanism	83·43
Hardware, cutlery and edge tools	74·98
Machinery	93·37
Castings and forgings	86·55
Railway supplies and rails	30·74
Other forms of iron and steel	60·07

Coal.—Coal will be required in the development of the iron industry. Very little Nova Scotia coal finds its way into Ontario, although the Dominion Coal Company say they probably placed about 500,000 tons west of Montreal in eastern Ontario during the year 1905. The consumption of bituminous coal in Ontario during the calendar year 1904 was 4,261,140 tons and of coal dust 612,222 tons nearly all of which was imported from the United States.

The total importations of United States coal and coal dust in 1906 was 5,492,974 tons, duty paid, $2,455,950.82; in 1907, 4,617,408 tons; duty paid, $2,081,492.41, and in 1908, 8,457,175 tons; duty paid, $3,593,427.70.

The cheapness of American coal at the mines and the short haul to the manufacturing towns in Ontario, notwithstanding the import duty, has practically shut out Canadian coal, therefore, the placing of Nova Scotia coal in Ontario must depend on improved transportation facilities. The Nova Scotia shippers are of the opinion that with such improvement they would be able to make some pro-

gress in this direction. In a statement respecting Nova Scotia's western market, the general sales agent of the Dominion Coal Company says: 'The geographic position of the Canadian and American coal fields and the conditions governing the distribution of the product have defined the boundary of the competitive markets, and any large increase in the consumption of Nova Scotia coal will now depend on such improved transportation facilities as will enable us to invade the Ontario market. The proximity of the inland provinces to the American coal fields and the cheap transportation afforded by the Great Lakes at present renders this almost impossible. In this connection the deepening of the canals has been strongly urged and with better facilities in this respect some progress might reasonably be expected. Of the Nova Scotia coal shipped to Quebec a considerable quantity was transhipped to Montreal and distributed over the eastern counties of Ontario, but this trade is limited and is only preserved to Nova Scotia by the duty on American coal. Territorially the Canadian market for Nova Scotia coal *under existing conditions* may be said to have reached its limitations.'

A recent publication entitled 'Coal' analyzing the trade between Canada and the United States, commenting on the above, says—'It is true that the St. Lawrence canals, now fourteen feet deep, can be deepened to allow a class of colliers on the Sydney-Montreal trade to proceed to the lake cities without breaking bulk, and doubtless that would be done hereafter should important interests demand it. Such vessels might become competitors for western grain freights.'

'With the advantage of return cargoes, Ontario would become practically independent of the United States for her supply of bituminous coal. That province could well consider the economy of appropriating a portion of her contribution to coal duties to the work of deepening the canals to secure cheaper coal from the deposits at the seaboard. The argument is, therefore, strong that her material interest will require her to either seek the removal of the duty on coal in both countries, or failing that to adopt the policy of deepening the St. Lawrence canals.'

The advantages of the Georgian Bay ship waterway are apparent, as the Canadian coal shipped via the St. Lawrence comes directly in competition with United States coal, the route being along the international boundary. The proposed waterway, however, would carry it through the heart of the province, rich in minerals, the highest development of which depends upon coal.

Delivery can be made as advantageously to interior points in Ontario, from the line of the Ottawa route, as from St. Lawrence, Lake Ontario or Lake Erie ports.

The average lake rate on coal from Lake Erie to Lake Huron and Georgian bay ports is 35 cents per ton. The average rate to Upper Lake ports is 40 cents per ton. The average rail rate from the mines to say Cleveland is about 78 cents per ton, making a through rate of $1.13 to $1.18 respectively.

The average rail haul from the mines to the lake front is 140 miles. From Cleveland to Fort William about 800 miles—total 940 miles. Vessels engaged in this trade usually secure return cargo.

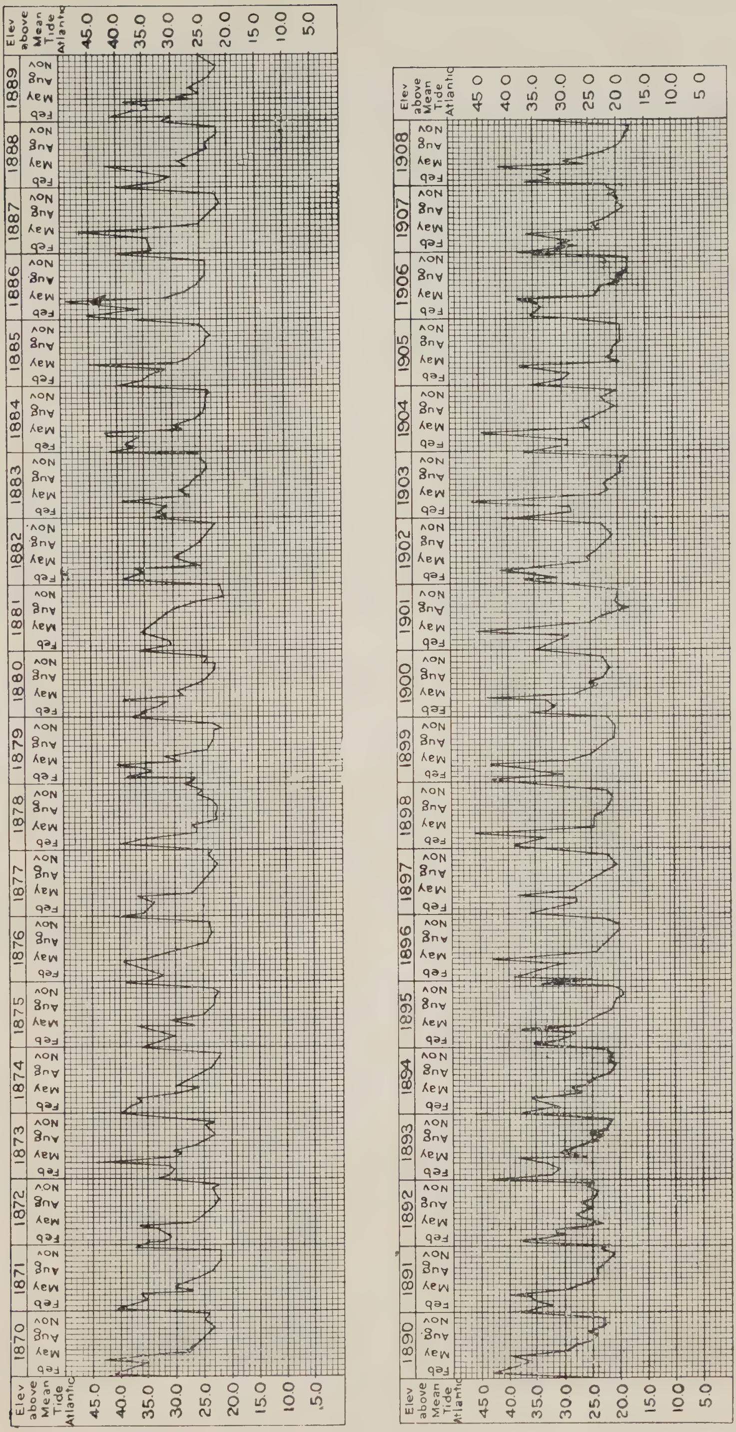
The distance Sydney to Montreal is 815 miles, Montreal to Fort William 882 miles, total 1,697 miles. Taking the lake rate Cleveland to Fort William as a basis, the rate Sydney to Fort William would be about 85 cents per ton as against a rate of $1.18 from the United States mines, with the advantage of non-transhipment.

It will be noted that there is a difference of 33 cents per ton in the rate of freight to Fort William in favour of Canadian coal. To this add the duty of 53 cents per ton making 86 cents per ton in all in favour of the home product.

Lumber.—The waterway will be of value to the forest wealth generally throughout the Ottawa valley.

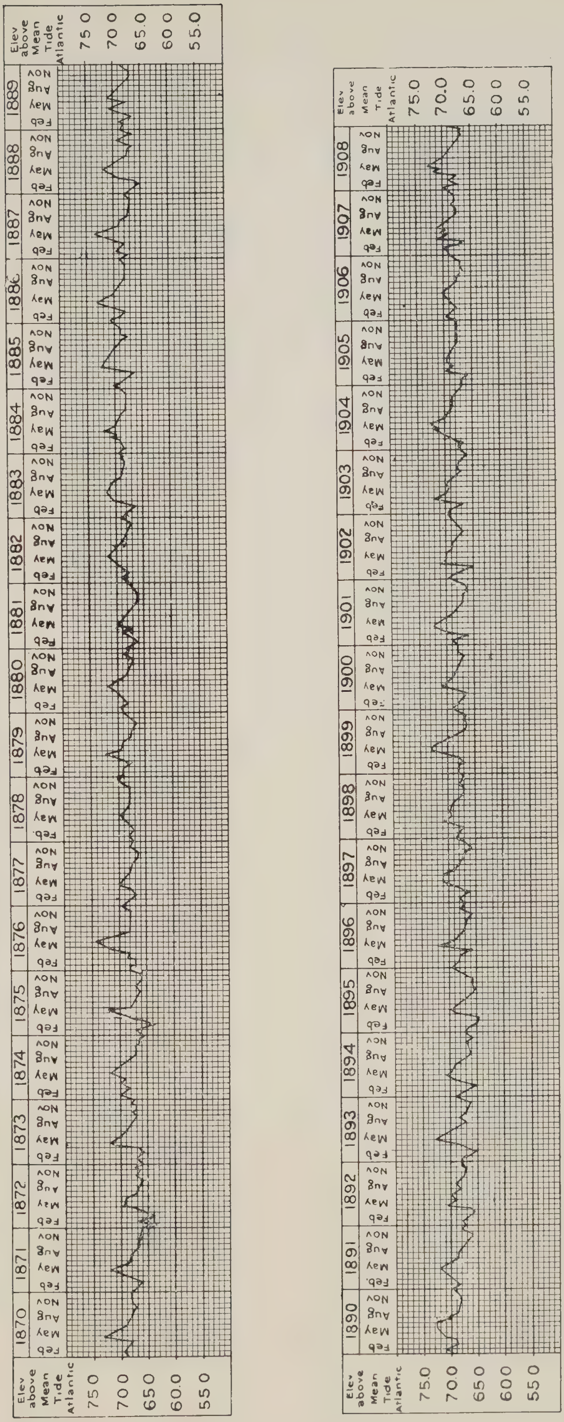
It will open to the lumber trade of the Ottawa valley the important markets of the Great Lake region. The receipts of lumber in Chicago for 1904 aggregated

1,670,272,000 feet. Buffalo is also an important distributing point for Canadian lumber. Pine has been the chief wood manufactured heretofore, but large areas of hardwood have been left standing. There has been quite a decrease in the quantity of hardwood exported, partly, because nearly all of this valuable wood, which is easy of access, is in the hands of manufacturers who refer to hold it for their own use. A water route would give access to hardwood areas, not only for export, but for home manufacturers. It will make possible the transport of large quantities of pulpwood, cordwood, bark, &c., which finds a ready market. Instead of the mills being centered in one district as at present they will be scattered along the entire route to the advantage of the trade generally.

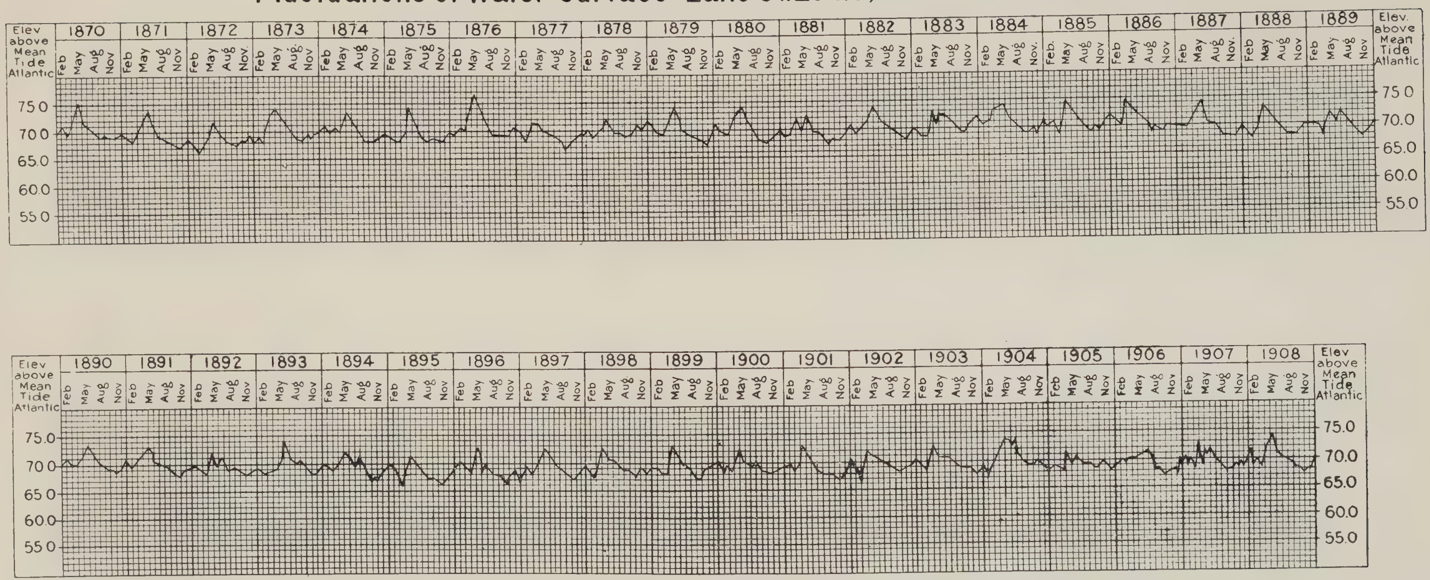


Fluctuations of Water Surface-Montreal Harbour, Foot of Lachine Canal.

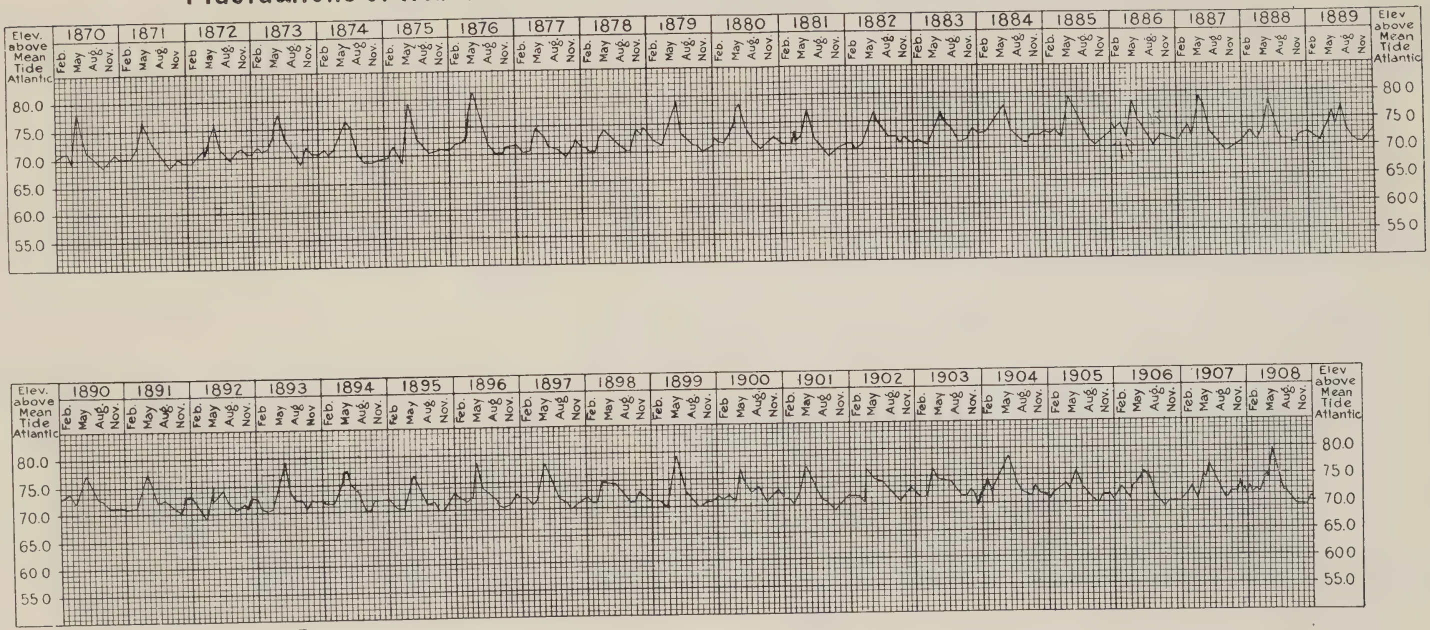
Fluctuations of Water Surface-Lake St. Louis, Head of Lachine Canal



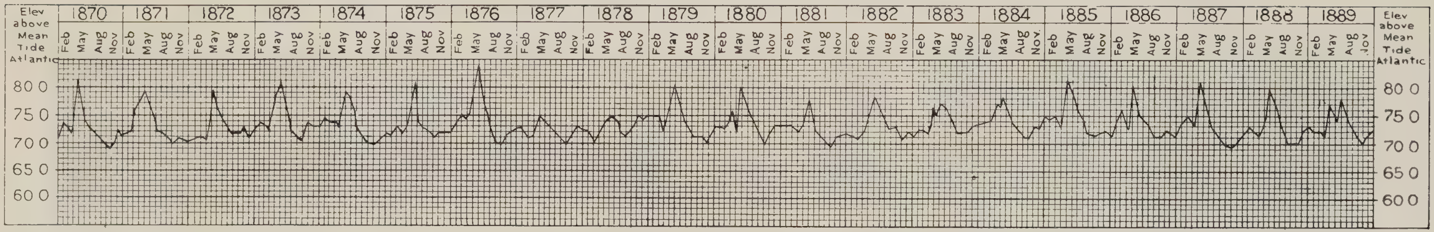
Fluctuations of Water Surface - Lake St. Louis; Foot of Ste. Anne Lock

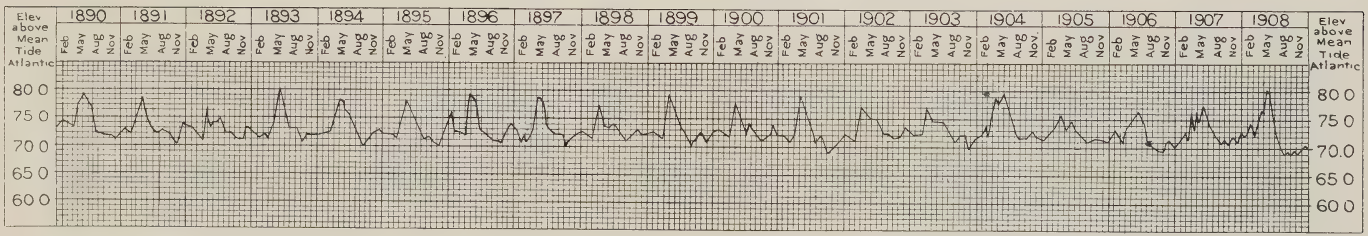


Fluctuations of Water Surface-Lake of Two Mountains, Head of Ste. Anne Lock

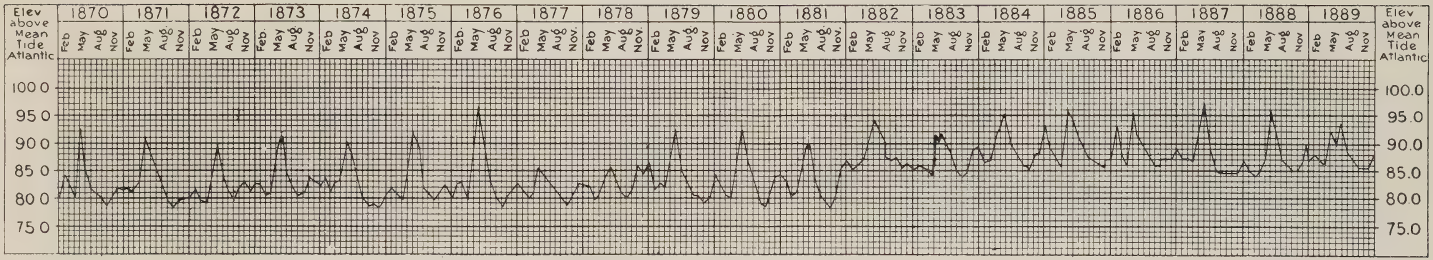


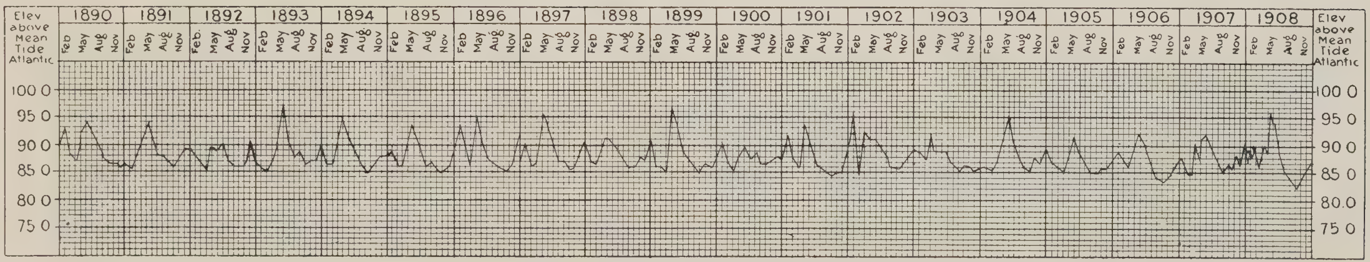
Fluctuations of Water Surface-Lake of Two Mountains, Foot of Carillon Canal



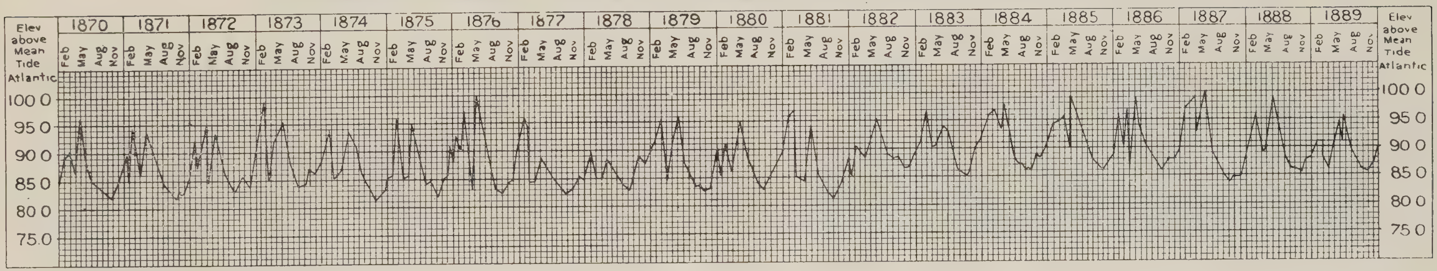


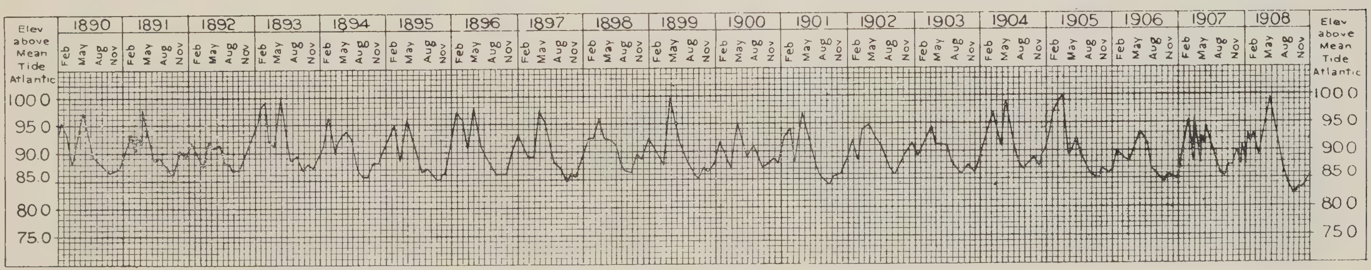
Fluctuations of Water Surface-Ottawa River, Head of Carillon Canal



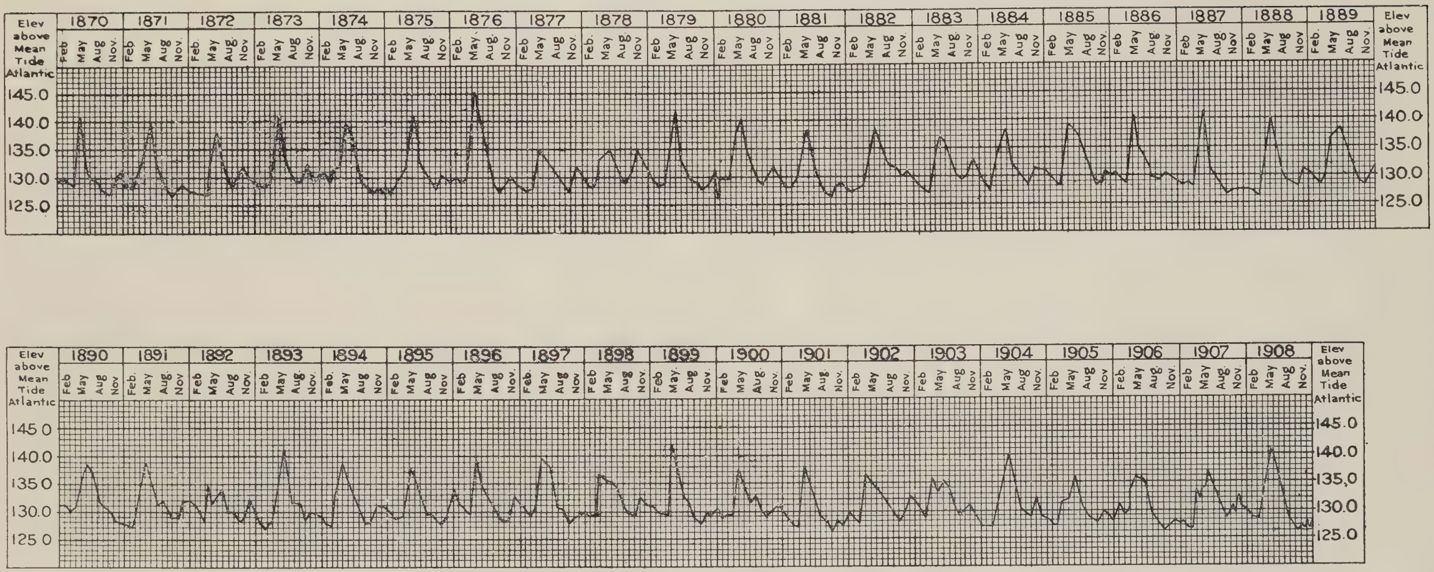


Fluctuations of Water Surface-Ottawa River-Foot of Grenville Canal.





Fluctuations of Water Surface - Ottawa River, Head of Grenville Canal



Fluctuations of Water Surface-Ottawa River, Foot of Rideau Canal